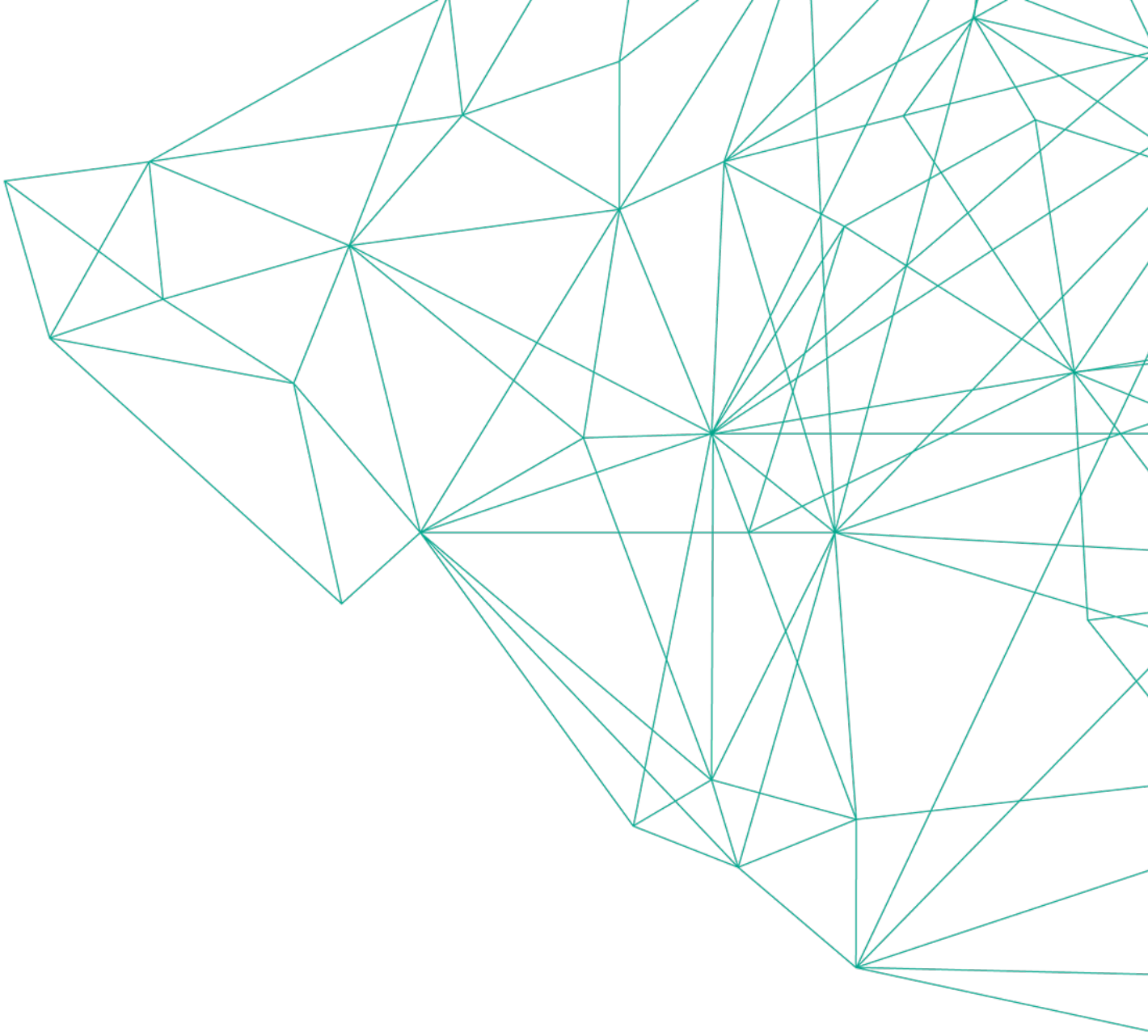


GUIDE TO NC DC

Explanatory guide on how to connect a demand facility to the transmission grid
June 2024

10 June 2024

Please note: This translation of the original Danish text is for informational purposes only and is not a substitute for the official Danish text. The English text is not legally binding and offers no interpretation on the Danish text. In case of inconsistency, the Danish version applies.

Doc. 17/07437-95 Offentlig/Public

ENERGINET
Systemansvar

Contents

1. Introduction

The purpose of this document is to explain the requirements that Energinet has for the connection of demand facilities to the transmission grid.

The target group is persons with no previous experience of connections to the public electricity transmission grid and persons without a technical background.

The document is neither technically nor legally binding and in case of discrepancies, reference is made to the applicable rules, which can be found on Energinet's Danish website *Regler* (https://energinet.dk/regler/) under *Regler for net-tilslutning* (grid connection) and *Regler for systemdrift* (system operation), respectively. Some requirements have already been translated and can be found on our English website *Rules, regulations, conditions, and methods* (https://en.energinet.dk/rules-regulations-conditions-and-methods/electricity-rules-conditions-and-methods/).

This document is not an exhaustive list of requirements for connection to the transmission grid, and the applicable rules are subject to change after the publication of this document.

If you have any questions, please contact us at TeamTilslutning@energinet.dk.

2. Basis

All the requirements described in this document are based on:

- Commission Regulation (EU) 2016/1388 of 17 August 2016 establishing a Network Code on Demand Connection (NC DC).
- Energinet's simulation model requirements, submitted on 08-09-2022, which are expected to be approved by the Danish Utility Regulator shortly.
- Technical regulations on demand connection, namely Technical regulation 3.4.2 Manual load-shedding of transmission-connected demand facilities and Technical regulation 3.4.3 Requirements for transmission-connected demand facilities.

All updated requirements for grid connection of demand facilities are available on Energinet's website Regler: energinet.dk/regler/el/nettilslutning under the heading Forbrug (demand).

Requirements for the operation of demand facilities can be found here: energinet.dk/regler/el/systemdrift under the headings Forordninger (EU regulations) and Tekniske forskrifter (Technical regulations).

Some requirements have already been translated and can be found on our English website *Rules, regulations, conditions, and methods* (https://en.energinet.dk/rules-regulations-conditions-and-methods/electricity-rules-conditions-and-methods/).

3. Process

During the project maturation process, Energinet provides guidance to the system user on the technical requirements applicable to the specific facility. Based on the system user's choices during the process – e.g. in relation to load-shedding, documentation of voltage quality, and facility design – Energinet reports are prepared on short-circuit levels and power quality requirements. The above examples are not exhaustive.

Changes to the capacity first submitted or the introduction of technology types other than the ones first submitted – including generation, energy storage, or co-located facilities – will result in a re-screening of the system user's project. It is also possible that the system user may be required to comply with other requirements and rules.

4. Technical aspects

Abbreviations

NC DC	EU Regulation *Network Code on Demand connection*
NTA	Grid connection agreement
P_n	Nominal output
MW	Megawatt
PFAPR	Post Fault Active Power Recovery
FRT	Fault Ride Through
POC	Point of Connection
SLD	Single-line diagram
POW	Point on wave
EON	Energisation Operational Notification
ION	Interim Operational Notification
FON	Final Operational Notification
TR	Technical regulation

4.1 Load-shedding

Explanation

Load-shedding is defined as a facility's ability to reduce its power draw from the transmission grid within a given time and power limit.

Why

The purpose of load-shedding is to reduce the power draw on the public electricity transmission grid, either due to overload of components such as transmission lines or in the event of voltage drops and frequency changes that can occur if large generation facilities disconnect.

Energinet uses four different types of load-shedding, which are described below.

4.1.1 Manual load-shedding

Explanation

Manual load-shedding is the slowest of the load-shedding methods. For manual load-shedding, the system user is assigned 10 or 16 load-shedding steps for DK1 and DK2, respectively, or the system user may, by agreement with Energinet, choose to disconnect the facility in one step.

The system user must, in accordance with the respective ordered load-shedding step, reduce the facility's power consumption within 15 minutes of activation. The system user decides how this downward regulation is distributed internally.

Why

Energinet designs the transmission grid and its components to be able to handle an overload for 15 minutes. Thus, manual load-shedding is intended to relieve load on the transmission grid within this timeframe under controlled conditions.

4.1.2 LFSM-U

Explanation

Limited Frequency Sensitivity Mode – Underfrequency is a requirement only applicable to demand facilities with capacities of 200 MW or more (see 4.6).

As with automatic load-shedding (LFDD) (see 4.1.3), the system user must monitor the grid frequency. The frequency limit monitored for this requirement is higher than for automatic load-shedding (LFDD) (49.5-49.8 Hz). This type of load-shedding must be initiated as soon as possible, however within 2 seconds at the latest.

Why

The LFSM-U requirement, which is only applicable to very large facilities, is closer to the grid frequency as it seeks to initiate load-shedding of very large demand facilities early in the event of a frequency dip, before all connected facilities are forced to activate automatic load-shedding (LFDD).

4.1.3 Automatic load-shedding

Explanation

Automatic load-shedding (LFDD) is the fastest form of load-shedding. Load-shedding is divided into 6 and 5 steps in DK1 and DK2, respectively, and must be activated automatically in the event of a drop in the grid frequency. The system user monitors the grid frequency in the POC. A load-shedding step must be completed within 150 ms (milliseconds).

Automatic load-shedding (LFDD) follows LFSM-U in the frequency band (48-49 Hz in DK1 and 48-48.8 Hz in DK2).

Why

Automatic load-shedding (LFDD) is intended to counteract drops in the grid frequency by quickly shedding load. Frequency drops may be due to the disconnection of major generation facilities connected to the transmission grid, or it may be due to the too sudden connection of high levels of load/consumption.

4.1.4 System protection

Explanation

System protection is Energinet's emergency tool, which is installed, but not always activated, in all facilities. It is a protective function that allows Energinet to counteract overload due to power inadequacy. System protection is only activated in facilities where Energinet finds that there is a high risk of overload to the public electricity transmission grid.

The load-shedding function is divided into 5 steps. The system user is responsible, through hardwired signals (4.16), for ensuring that the facility can shed load in line with the requirements.

Why

System protection is faster than manual load-shedding (1 second until start and 10 seconds until completion) and can therefore be used to counteract any unexpected overload in the transmission grid. As all facilities are equipped with system protection, Energinet can shed load in large areas using the same signal. However, this requires system protection to be activated and ready for use which Energinet may require at any time subject to 15 minutes' notice.

4.2 Protection

Explanation

Energinet requires that the system user protects its own facility and Energinet-owned components as well as the public electricity transmission grid. To achieve protection redundancy, Energinet requires the installation of two mutually independent relays. The relays must be of different types, e.g. differential and overcurrent relays. The relays must not be situated in the same physical unit.

Why

The purpose of the protection requirements is to protect both the public electricity transmission grid and the facilities connected to it.

4.2.1 Cable protection

Explanation

To enable the system user to protect the cable to the facility, the installation of differential protection incorporating the Energinet-owned relay and circuit breaker is permitted. Energinet only allows opening/disconnection using the Energinet-owned circuit breaker; Closing/connection must always be handled by Energinet's Control Centre.

Energinet's protection only covers a section of the system user's cable, and Energinet therefore accepts no responsibility for monitoring cable faults.

Why

Cable faults may result in costly and time-consuming replacements or repairs. To enable the system user to protect the cable, protection is coordinated through Energinet's circuit breaker.

4.2.2 Bay and circuit breaker

Explanation

Energinet requires that the system user designs, purchases, and establishes a fully equipped bay between the POC and transformer. The panel must be equipped with circuit breaker, disconnector, and earthing switch. The establishment of surge protection is recommended.

Why

The system user is required to be able to protect its own facility, Energinet-owned components, and the public electricity transmission grid. Furthermore, Energinet is not liable for damage to the system user's facility owing to a lack of self-protection, including loss of earnings.

4.3 Transformer type and star point earthing

Explanation

Energinet requires that the primary side of the transformer is star-connected with established star point earthing. To protect Energinet-owned equipment, any star points on the secondary side cannot be earthed in such a way that this may influence Energinet's use of star point earthing.

Why

Energinet ensures efficient earthing of own facilities and the public electricity transmission grid. It is therefore necessary that Energinet has the possibility, if so ordered, to earth all connected facilities.

4.4 Temporary overvoltages and POW equipment

Explanation

A temporary overvoltage is a phenomenon that can occur during the energisation of transformers, cables, or other equipment. A temporary overvoltage is when one or more phases are briefly subjected to an increase in voltage. This may cause damage to own or Energinet-owned facilities. To counteract this effect, Energinet may require the use of synchronized circuit breakers, so- called Point-on-Wave (POW) equipment.

The need is assessed based on, among other things, the size(s) of the transformer(s) and the length of the cable(s) established by the system user.

Why

As Energinet requires that system users do not cause damage to Energinet-owned equipment or negatively impact the public electricity transmission grid, it may be necessary to install POW equipment.

4.5 Ramp speed

Explanation

The system user must comply with requirements for how quickly power absorption from the public electricity transmission grid is increased or decreased. The requirement is 20% of P_n/min., however, maximum 60 MW/min. Upward and downward regulation of power demand must be done as an approximate linear function.

Why

The purpose of the requirement is to prevent situations where overvoltage or undervoltage may occur due to rapid changes in consumption. Furthermore, the requirement allows Energinet's Control Centre to react in time and thus be able to balance the electricity system.

4.6 Facility category and expansion plans

Demand facilities in the transmission grid are divided into the categories 3, 4, 5, and 7.

Categories

- 3: A facility where it can be demonstrated at the time of obtaining the ION/FON that the full power draw assigned can be utilised from day one.

- 4: A facility where it cannot be demonstrated at the time of obtaining the ION/FON that the full power draw assigned can be utilised. Category 4 facilities require the preparation of an escalation plan during the maturation phase.

- 5: A facility where it can be verified that the full power draw can be utilised, but with 500 or fewer full-load hours in a year.

- 6: This category is used for third-rail current systems for railways.

- 7: A facility with a requested power draw of 200 MW or more. Category 7 facilities are subject to several additional requirements, including PFAPR, LFSM-U (see under protection), and FRT.

4.7 PFAPR

Explanation

PFAPR, or Post Fault Active Power Recovery, is a requirement for category 7 facilities.

This requirement states that category 7 facilities must be able to resume facility operations following a grid fault. Within 5 seconds of grid normalisation, the facility must be operational, drawing at least 80% of power used prior to the grid fault. After 30 seconds, the facility must be operated at 90% of power used prior to the grid fault.

Why

The aim of this requirement is to ensure stability in the public electricity transmission grid.

In the event of a short-term generation facility disconnection or tripping/reclosing of a transmission line, this requirement helps to ensure that the transmission grid maintains a certain amount of load compared to before the fault. This is intended to prevent overvoltages due to a lack of demand.

4.8 FRT

Explanation

Fault Ride Through is a requirement for category 7 facilities. The facility must be able to remain connected to the transmission grid in the event of a voltage dip.

The requirement defines how many seconds the facility must remain connected based on how sharp the voltage dip is.

Why

For example, a brief voltage dip may be caused by the momentary disconnection of large production units and the tripping or reclosing of transmission lines. To avoid a subsequent voltage increase, demand facility must remain connected.

4.9 Single- line diagram and signal lists

Single-line diagram (SLD)

Explanation

An SLD must be submitted during the maturation phase to allow Energinet to gain knowledge about the facility. An SLD must be prepared in accordance with applicable standards, including naming of components, bay names, and ownership limits. The SLD must be submitted as early as possible, and experience shows that it is an iterative process. It is recommended to start work on the SLD as early as possible.

Why

Energinet must know what is connected to the public electricity transmission grid, and it is therefore necessary to submit an SLD. An SLD shows Energinet what the system user is building and thus allows Energinet to provide guidance on the correct rules.

Incorrect transformer earthing, incorrectly equipped bay, potential for parallel switching, and equipment not mentioned earlier in the unit are among the things discovered upon receipt of an SLD, allowing Energinet to provide correct guidance to the system user in due time.

In addition, Energinet uses the SLD for verification of simulation models, SCADA system, hardwired signals, and regulation signals.

4.10 Signal list

The two signal lists prepared during connection are intended to coordinate protection between the system user's facility and Energinet and to define for which components in the facility measurements or status indicators are needed.

4.10.1 Hardwired signal list

Explanation

During the maturation phase, after Energinet has received an SLD, the hardwired signal list is compiled.

Why

The hardwired signal list is used to coordinate, among other things, protection between the system user's and Energinet's facilities.

4.10.2 Regulation signal list

Explanation

After receipt of an SLD, Energinet prepares the regulation signal list.

This signal list specifies the signals to be sent to Energinet and the data that these signals must contain. Examples of this are circuit breakers and earthing switches, where the signal must contain switching status.

Why

Energinet uses these signals to monitor facilities connected to the public electricity transmission grid. The signal list is included in Energinet's SCADA system.

4.11 Simulation models

Explanation

Energinet requires simulation models for the facility. This is necessary for Energinet to know how the planned facility will affect the public electricity transmission grid.

The following models are required:

- Static simulation model
- RMS simulation model
- Harmonic simulation model
- EMT simulation model

The models are delivered in PowerFactory and PScad, respectively.

For PowerFactory, the following packages are required to generate models:

- Basic package
- Power Quality and harmonics
- Stability analysis functions (RMS)

In addition, it is recommended that the following packages be used:

- Protection functions
- System parameter identification.

During the maturation phase, Energinet offers the system user a review of models and requirements with a representative from Energinet's simulation department.

Why

Submitted simulation models are used to check that new facilities do not have a negative impact on the public electricity transmission grid. In addition, Energinet uses the models to create simulations and calculations to ensure that the public electricity transmission grid has the capacity needed to handle current and future connections.

4.12 Power quality

Explanation

Energinet requires that no harmonic noise is introduced into the public electricity transmission grid.

During the maturation phase, a power quality report will be prepared. This is prepared based on the demand facility's transformer size, length of cable(s), and the chosen method for verification of voltage quality.

There are two possible options:

- Verification of requirements using the allocation of a fixed harmonic voltage distortion contribution
- Verification of requirements using background noise measurements.

The first method sets stricter requirements for the system user's compliance with requirements, but verification can be achieved with a written report stating that the installation has little or no impact on the transmission grid.

The second method has less stringent requirements than method 1; Here, however, compliance must be documented with simulation models.

As a rule, method 1 is intended for facilities where no significant power electronics are involved, but where the system can primarily be regarded as an ohmic resistance, whereas method 2 is used for facilities with a lot of power electronics and/or different types of technology.

It is the system user's responsibility to compensate for the facility using filters.

Why

Energinet requires that the system user has no negative impact on the public electricity transmission grid. Therefore, it is required that the system user compensates for, among other things, harmonic noise.

4.13 Reactive power and cos phi

Explanation

Energinet requires compliance with reactive power and cos phi.

Reactive power is power [VAr] used, among other things, for the excitation of transformers or large electric motors. Reactive power is generated when the current through, for example, a transformer decreases.

Active power and reactive power occupy the same 'space' in the transmission grid. As only active power utilises electrical energy, it is necessary to keep reactive power at the correct level to ensure optimum utilisation of the public electricity grid.

Cos phi is an expression of the ratio between active power and reactive power: $\mathrm{Cos}(phi) = \frac{P}{Q}$, where P is active power and Q is reactive power. The system user must comply with cos phi >0.99, and a maximum of +/- 15 MVAr may be exchanged.

Why

The purpose of this requirement is to keep reactive power in the public electricity transmission grid at a manageable level. Since reactive power and active power occupy the same 'space', too much reactive power may result in a need for unnecessary and expensive expansion of the public electricity transmission grid.

If necessary, the system user is required to compensate for this requirement. The requirement always applies, also in the event of a temporary change in grid voltage or in connection with energisation of the facility and any compensatory equipment. Consequently, it is recommended to consider these requirements when dimensioning the transformer.

4.14 EON

An EON, or Energisation Operational Notification, is the permission issued by Energinet to the system user to energise a facility. The energisation permission allows energisation of facilities and auxiliary systems.

During EON operation, power exchange with the grid is not allowed.

The EON period is used to run initial tests to ensure that the facility complies with the requirements set by Energinet and that a correct connection to Energinet's SCADA system has been established.

An EON will only be issued when the system user has obtained approval of the required simulation models, signal lists, SLDs, and similar.

4.15 ION

Once the system user has completed the initial tests of the facility under the EON, the system user can apply for an ION, i.e. an interim Operational Notification.

The system user is allowed to exchange power with the public electricity transmission grid during ION operation.

The ION period is used to demonstrate to Energinet that the facility complies with all technical requirements, including load-shedding, reactive power exchange, and ramp rates for upward and downward regulation of active power, and to demonstrate that the submitted simulation models match the physical facility.

An ION is issued by Energinet for a period agreed with the system user. If the system user finds it necessary, it is possible to apply for an extension of the ION period. The ION validity period is maximum 24 months.

4.16 FON

After complying with the requirements during the ION period, the system user may apply for an FON, Final Operational Notification.

Energinet issues a FON when the system user has demonstrated to Energinet that the facility complies with all

technical requirements and rules. By issuing a FON, Energinet thereby 'lets go' of the project and considers it completed. The system user then transitions to day-to-day operation.

Every three years, the system user is required to carry out a 'self-assessment' to document to Energinet that the system user is still able to meet the requirements set out in the grid connection agreement for the facility.

5. Exemptions and derogations

5.1 Exemptions from technical regulations

System users may seek an exemption from some of the requirements set out in the technical regulations (TRs). To be considered for this, the system user must account for a number of points specified under the respective requirements and rules.

Among the points that must often be accounted for are that:

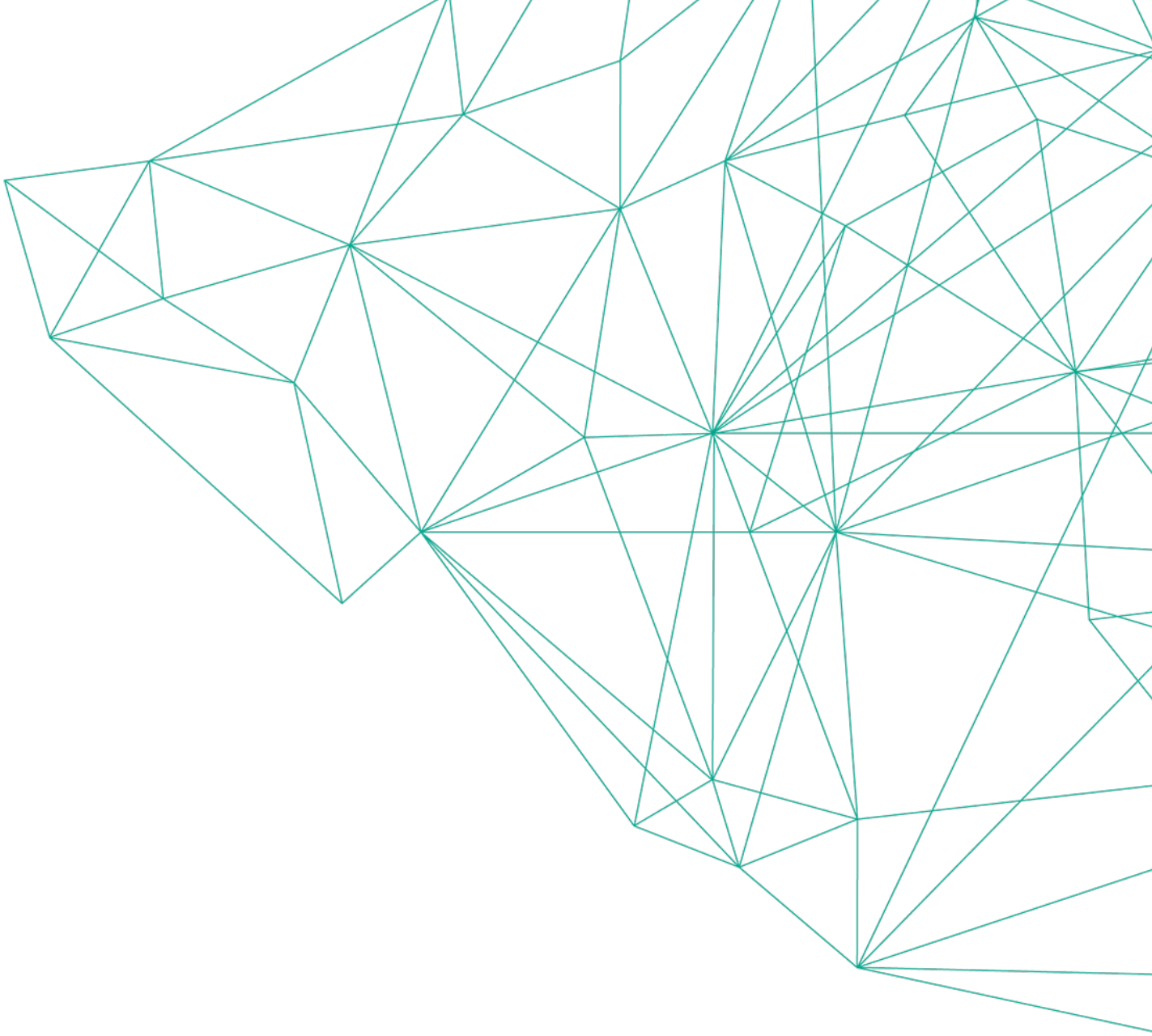
- Compliance is technically unattainable
- Non-compliance does not adversely impact the public electricity transmission grid
- Compliance does not make socio-economic sense
- Non-compliance has no impact on other system users.

The application is completed and submitted to Energinet. Energinet will then assess whether an exemption can be given.

If an agreement is not reached between the system user and Energinet, the system user may file a complaint and/or have the matter settled by the Danish Energy Agency.

5.2 Derogation from the regulation

If an application is made for an exemption or derogation under the rules set out in the regulation, an application must be made to the Danish Utility Regulator and not Energinet.



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Published June 2024

Author: HHU/LVT

Date: 03 June 2024