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Smart integRation Of local energy sources and innovative storage for flexiBle, secure and cost-efficIent eNergy Supply ON industrialized islands

D 1.2 – Reports on the legal and regulatory aspects

Lead partner: RES-T

Project Contractual Details

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Executive summary

Deliverable 1.2 of the ROBINSON project corresponds to Task 1.2 that is entitled "Legal and regulatory aspects for integration of the DER." The objective here is to review the current situation at the demonstration island, Eigerøy, in Norway, and on the follower islands, Crete in Greece, and the Western Isles in Scotland. The outcome will be used as a baseline for all other technical work packages and tasks.

There are no uniform standards for getting operation permits throughout Europe. Nationally/regionally, the same value system (protection of the environment) is applied in principle, but possibly with different limit values, e.g. for distance requirements, emission limits, etc. This has a great influence on the economic viability of DER systems, e.g. if the use of wind energy in the vicinity of the consumer cannot be approved.

The proposed DER systems within the Robinson project use electricity, heat and gas grids. In parallel to the "general" authorisation procedure, the granting of an authorisation for the possibly also only temporary operation of the subsystems to a grid is required by its grid operator. The rules and proofs required for the connection are determined by the respective network operator. These are more or less based on national or international standards.

Due to transnational electricity and gas grids, the EU Commission has requested its member states (MS) to harmonise the connection requirements for non-discriminatory and competitive access. The Entso-E (electricity network) and Entso-G (gas network), among others, have developed and are developing general and concrete guidelines and framework conditions. For electricity grids, the network code on requirements for grid connection of generator (RfG NC) is relevant, which must be implemented in national connection conditions in the individual MS.

The framework for the definition of the so-called non-exclusive requirements in the RfG NC by the MS is the standard N 50549 1/2, which was developed in parallel by the European Committee for Electrotechnical Standardization (CENELEC) (CLC/TC 8X).

However, these specifications/guidelines do not yet sufficiently include the design of DER systems with their multitude of possibilities for energy conversion and storage.

The EU Commission has reacted to this by forming/supporting working groups that are developing proposals for adaptation to future DER systems.

Internationally, especially in the US, standards already exist for DER systems (often arranged in the form of so-called microgrids) to link microgrids with distribution/transmission grids.

Due to the manageable interaction of entry and exit processes in a gas grid, there are no uniform standards harmonised across Europe regarding the connection of systems to a gas grid. However, national standards all have very similar requirements.

International heating networks are not/barely available, so only local requirements by network operators exist here.

Impact on the Robinson demo project Eigerøy:

The Eigerøy demo project serves as an example for the implementation of the approaches to DER systems developed in the Robinson project.

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The realisation of the demo project in Eigerøy must comply with the local requirements of the approval authorities for a general operating permit. The approvability of one or more larger wind turbines located close to the consumers, which due to the very good wind conditions could make a large contribution to supplying not only the current single industrial consumer (Prima Protein), is not realistic due to the approval practice in Norway/Egersund (priorities for the protected goods human / nature). The inclusion of energy storage such as batteries or e-mobility are also not planned. The heat and gas grids required for the planned subsystems are located on the consumer's property. Therefore, the only interface of the planned DER system on Eigerøy is a connection to Dalane Energi's electricity distribution network.

For the connection of the individual electricity-generating subcomponents to the local electricity distribution network of Dalane Energi, it must be taken into account in the opinion of the author that these are to be connected to the internal network of the consumer Prima Protein in the sense of the definition POC. Thus, in view of the connection conditions specified by the distribution grid operator, the entire new electrical connection capacity of currently 500 kW (100 kW wind energy and 400 kW CHP) would have to be taken into account and treated as one unit. The connection conditions are formulated in RENblad 3xx (as of 2009). These therefore do not yet take into account the current national implementation of the RfG NC by the NVE. These are available as consulation draft NvF 2021.

For the concrete design of further DER systems in the follower islands, the topology (where the POC is located, voltage level < 110 kV) and the size must be taken into account with regard to the requirements for the connection of subsystems, as this results in the classification into the category type A or type B with, in part, nationally different power limits and requirements defined accordingly.

Outlook

DER systems will play an increasing role in the future energy supply in Europe and worldwide. A systemic view in the case of distributed connections of subsystems to existing distribution grids or central connection conditions of DER systems organised in microgrids is necessary to enable or improve the integration and dissemination of DER systems.

Approaches for this are already being developed at the European level (see above), and this topic is also being addressed in the working groups within the framework of the BRIDGE Initiative.

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List of abbreviations

AC	Active current
CHP	Combined heat and power
DER	Distributed energy resources
EMS	Energy management system
RES	Renewable energy sources
WP	Work package
RfG NC	Requirement for generators Network Code
TSO	Transmission system operator
DSO	Distribution System Operator
NRA	National regulatory authority
EC	European commission
ACER	Agency for the cooperation of energy regulators
ENTSOE	European network of transmission system operators for electricity
PGUs	Power Generating Units
MCS	Mixed Customer Sites
PGM	Power Generating Module

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1. Introduction

The ROBINSON project "smart integRation Of local energy sources and innovative storage for flexiBle, secure and cost-efficIent eNergy Supply ON industrialized islands" aims at developing an integrated energy system to help decarbonise (industrialised) islands (geographical or virtual onshore islands). The project will develop and deploy an integrated, smart and cost-efficient energy system that couples thermal, electrical and gas networks; hence optimizing the utilization of local renewable energy sources (RES).

ROBINSON's main mission is to develop an integrated energy system tailored to islands with industrial activities coupling locally available energy sources, electrical and thermal networks and innovative storage technologies, and to demonstrate it on the island of Eigerøy, Norway. In order to achieve the target, innovative technologies will be developed, integrated on the island and managed by a novel energy management system (EMS) that will include non-electrical resources such as biomass gasification, wastewater valorisation and industrial symbiosis in terms of heat and oxygen reuse

As part of this project, work package 1 has a main objective to define boundary conditions (PHASE 1 – DEFINITION OF THE BOUNDARY CONDITIONS). Deliverable 1.2 is corresponding to Task 1.2 that is entitled "Legal and regulatory aspects for integration of the DER." In this tasks, the technical framework conditions to be considered when coupling DER systems with a (supra-regional) electricity grid in terms of EMS design will be worked out (by REST and the islands (ENH, UHI, TUC, CNES, KRITI) in collaboration with DALANE for the legal aspects).

- Analysis of EU and NO connection conditions and formulation of specifications derived from it for the system.

- Highlighting differences between regulations and resulting impact on designing DER systems

- Identification of gaps in the technical regulations and standards for connecting the planned reference system and, if necessary, working out solutions.

The outcome will be used as a baseline for all other technical work packages and tasks. The design of the system will consider possible effects of the regulations across the energy vectors as some differ in part between EU countries.

2. Overview of the Robinson DER System

ROBINSON's main mission is to develop an integrated energy system tailored to islands (whether these are geographical islands or virtual onshore ones) with industrial activities by coupling locally available energy sources, electrical and thermal networks and innovative storage technologies.

This does not mean the use of spatially widely distributed resources and the transmission of the converted energies via transmission or distribution networks to the consumer, but the use of resources in a spatial proximity to the consumer as well as the use of existing or, if necessary, supplementary local networks (electricity / heat / gas (H2)).

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In the following figures, the planned demo project for the island of Eigerøy (Fig.1), as well as the principle system layouts for the follower islands Western Isle and Crete are schematically shown. The general framework conditions for the three sites were explained in Task 1.1.

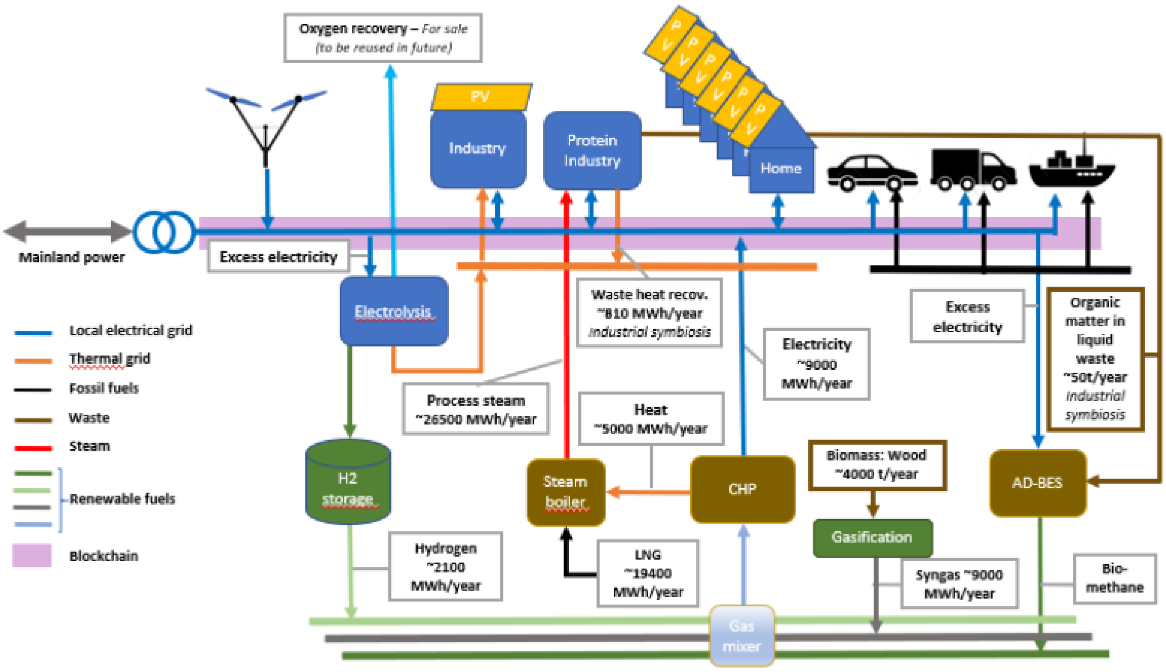

Figure 1 Robinsons system Eigerøy

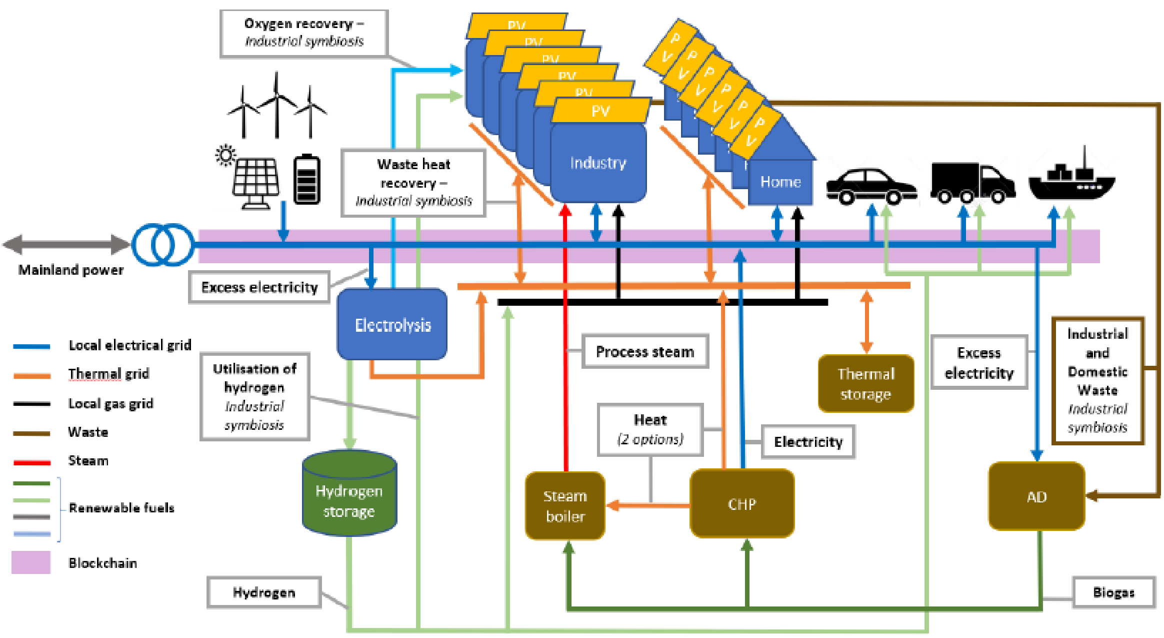

Figure 2 – System layout for the Western Isles

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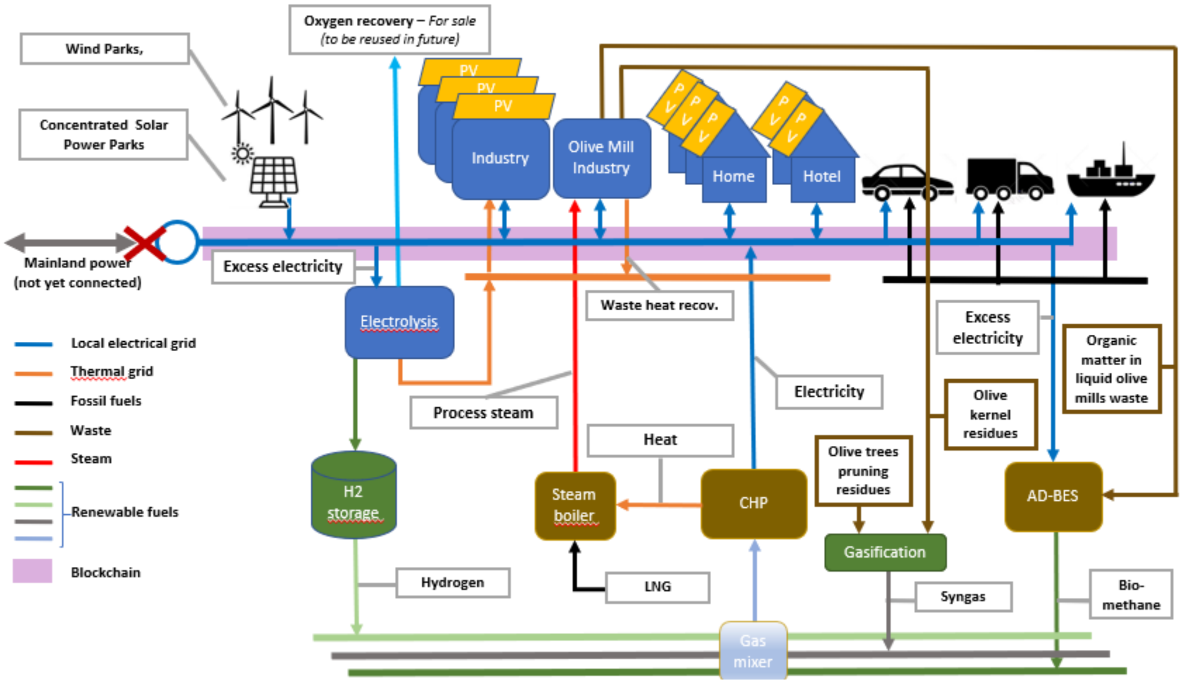

Figure 3 – System layout for Crete

The schematic structure clearly shows the importance of linking the different technologies and managing them via an EMS. An important task in the project is therefore the coordination of suitable specifications of the subsystems, the interfaces to each other and to connection systems, such as public electricity/gas and heating networks. In addition to the technical interfaces, however, it is also necessary to find a suitable operator structure that can handle the necessary processes: Approval, financing, construction, operation and dismantling for the realisation of a DER system. The demo project to be realised in Eigerøy is primarily about testing the interaction of different, partly new technologies in different grids (electricity/heat/gas) with the help of an EMS. This will take place at an industrial customer, who will also be the operator of the DER system, in its internal networks. In general, however, a far more heterogeneous operator and customer structure can be assumed when implementing DER systems (as is also the case in the Robinson Follower Islands). The analysis of the various Follower Islands (Task 1.1), however, reveals very different needs in principle. To what extent these should be covered by DER systems scaled in size or by the multiplication of smaller DER systems is currently open. In this context, the effects of regulations must also be taken into account.

3. Regulartory aspects with the realisation of DER systems

The construction and operation of technologies planned in DER systems are subject to various regulations that have to be considered depending on the type and size of the (sub)systems, the interfaces of these systems to higher-level network structures and the operator/customer structure. In addition to a general operating licence (if necessary for each sub-system, see below), agreements must be concluded with the operators of the DER systems to connect them to higher-level networks and their standards must be fulfilled.

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3.1 Operating permit

DER systems are designed to optimally utilise local, possibly regional energy resources for the supply of private and industrial consumers (electricity/heat/mobility).

Depending on the local resources, DER systems therefore consist of different energy generators/converters and storage systems that are regulated/controlled via an energy management system for a reliable, secure and cost-effective supply of the consumers. The scale of the systems depends on the local possibilities and requirements. Due to the flexible design based on the local situation, there is no **one** system.

The responsibilities and framework conditions for obtaining general operating permits for systems such as those to be used in the Robison project vary greatly in some European countries and depend on the size of the respective technical systems and processes applied for.

In the procedure for obtaining an operating licence, which is carried out by local administrative authorities, the effects of the proposed operation (of the subcomponents) on the (living) environment are assessed and weighed up. The applicant must provide information on: Operational safety, emissions, impact on nature (protected areas, flora/fauna) etc.

There are no universal standards for this throughout Europe. Nationally/regionally, the same value system (protection of the environment) is applied in principle, but possibly with different limit values, e.g. for distance requirements, emission limits, etc. This has a great influence on the economic viability of DER systems if, for example, the use of wind energy in the vicinity of the consumer cannot be approved. Essential here is e.g. the size and/or number of planned wind turbines. The scope of approval procedures for wind turbines depends strongly on this. In national procedures, a distinction is usually made with regard to the (maximum) height of the wind turbines, as this criterion correlates, for example, with environmental impacts such as emitted noise, shadow flicker, effects on bird migration and, in general, with acceptance by the population. In most countries, a significantly more complex procedure is required for wind turbines with a total height of 50 m above ground, with a large number of associations/persons to be involved. As a result, the open procedures may take several years and thus considerably longer than less complex procedures for other subsystems.

The application for an operating permit is made by the operator. However, since a DER system can involve a large number of different technical systems, which do not have to be spatially closely connected, there is no uniform, coupled authorisation procedure. This also applies if the DER system is to be relased with different operators for individual subsystems. For a holistic view, there is therefore always the risk that individual subsystems that are essential for economic operation may not obtain an operating licence..

3.2 Connection of DER systems to higher-level networks

The schematic diagram of the Robinsons systems (Figure 1-3) for the three example sites shows various connections of the individual systems to possibly customer-specific or regional distribution grids, which may in turn be connected to supra-regional transmission grids. For these grid connections, individual approvals by the respective grid operators are necessary, independent of the general (official) operating permit. Depending on possible effects and feedback effects on the grid, different connection conditions of the grid operators have to be fulfilled. For electricity and gas there is a well-established regulated governance process for the development of technical codes (for example the grid code) and terms for connecting to and using the network, including cost allocation

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methodologies. The process is broadly the same for the technical and semi-commercial codes, involving a) the opportunity for code signatories and interested stakeholders to put forward changes b) appointment of expert working groups to work up proposals which c) are then submitted to the regulator for approval. Some detailed industry recommendations are developed by specialist standards organisations. As part of the Single Electricity Market, a number of change proposals come direct from European harmonisation work. These processes have all evolved over time from a largely industry-led initiative with no independent oversight to an almost wholly regulated approach with detailed governance procedures. A defining feature of the gas and electricity networks is that they are large, interconnected and shared by ever-increasing numbers of connected demand and generation users. This drives both the content of the codes, and the industry / stakeholder dynamic in developing code change proposals. Due to the strong interaction between electricity consumers and electricity generators in a trans-European grid with the risk of international effects of local errors, there is a multitude of detailed regional/national connection requirements.

Since 2016, these are to be harmonised by EU regulations 2016/631 (*RfG NC 2016*). In a more diluted form, this also applies to gas grids and heat grids. But regulations in this regrard focus more on trade issues then describing technical requirements in detail.

4. Connection to electrical grid

4.1 Connection topologies and definitions

Depending on the connection concept/ownership boundary and voltage level, different connection constellations result. DER systems are characterized by the fact that instead of "single" power plants (e.g. combined heat and power plants, wind farm, solar farm), a combination of different systems are connected to a distribution or transmission grid, which also includes electricity storage facilities (batteries, motor vehicles).

Different terms are used with regard to the system to be connected. A uniform definition or designation in the various standards is not yet available. For further understanding, the following definitions are adopted here:

- Power Generating Module (PGM): means either a synchronous power-generating module or a power park module;
- Synchronous Power Generating Module (SPGM): means an indivisible set of installations which can generate electrical energy such that the frequency of the generated voltage, the generator speed and the frequency of network voltage are in a constant ratio and thus in synchronism;
- Power Park Module (PPM): means a unit or ensemble of units generating electricity, which is either non-synchronously connected to the network or connected through power electronics, and that also has a single connection point to a transmission system, distribution system including closed distribution system or HVDC system.

Electrical storage systems are defined as follows:

- Electricity Storage; - “The conversion of electrical energy into a form of energy which can be stored, the storing of that energy and the subsequent reconversion of that energy back into electrical energy”.

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- Synchronous Electricity Storage Module would be one in which the Storage Module converts electrical energy into a form of energy which can be stored, the storing of that energy and the subsequent re-conversion of that energy into electrical energy. The transfer (i.e. charging or discharging) of that electrical energy would be through ***one or more synchronous*** machines connected to the electrical network with a single connection point to the system.
- Non-Synchronous Electricity Storage Module would be one in which the Storage Module converts electrical energy into a form of energy which can be stored, the storing of that energy and the subsequent re-conversion of that energy into electrical energy. The transfer (i.e. charging or discharging) of that electrical energy would be through *an asynchronous machine or through a power electronic converter* connected to the electrical network with a single connection point to the system.

Note: while saying connected to the electrical network with a single connection point, that means to be able to charge/discharge through a single connection point (an Electric Vehicle can be connected to different charging stations, depending on its location, but once it's connected to a charging station, the EV is able to charge or discharge from this connection point).

The following figure shows different scenarios, which are divided according to the voltage level at the connection point and the respective power of the individual systems.

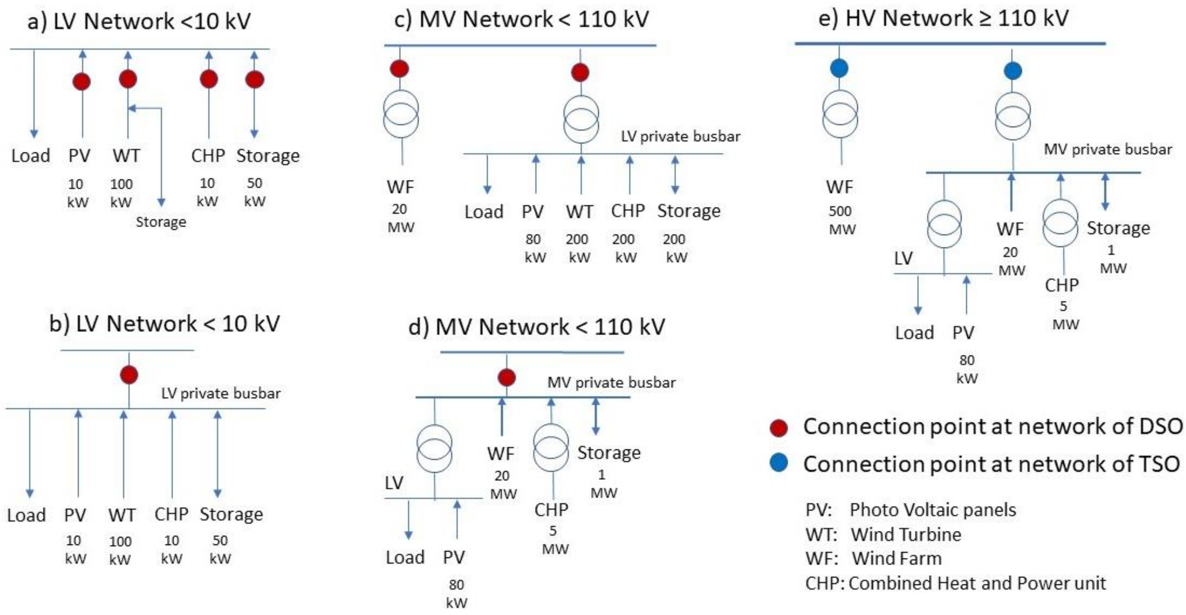

Figure 4 Examples for Single and Mixed Custome Site Connections

In a), individual PGMs and low-power storage units are connected directly to a low-voltage grid[2]. For each system, the connection conditions of the grid operator must be fulfilled. A distinction must be made between the connection of a storage system in synchronous operation to the higher-level grid,

[2] To define normal and abnormal operating conditions, thresholds are set based on the value of one of the fundamental characteristics of the system. Voltage is the variable that is observed and measured in both magnitude and frequency. Therefore, it is essential that the point in the system where this variable is to be observed and measured is specified. Two different points of the network are typically considered to specify the reference measurements, either in point of common coupling (PCC) or in point of connection (PoC). PoC is located at the DER's output, and PCC is defined as the interface at which the DER is connected to a public distribution network.

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which can then be controlled, and whether the storage system is connected to a PGM and thus decoupled from grid operation.

In b), different systems as well as the consumers (load) are first connected via a LV busbar and are then connected to the superordinate grid via a central connection point. There are different definitions for such connection concepts depending on the design:

Closed Distribution System (CDS):

Article 28 of Directive 2009/72/EC defines such a system as a system which distributes electricity within a geographically limited industrial, commercial or service area and (without prejudice to a small number of households located in the area served by the system and linked to the system owner by an employment relationship or in a similar way) does not supply household customers.

The closed distribution system is either integrated for specific or technical reasons into the operation or production process of the users of the system or distributes electricity primarily to the owner or operator of the closed distribution system or to undertakings affiliated to it.

Microgrid[3]:

According to U.S. Department of Energy (DOE 2011) a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode.

The reference to an American definition already indicates that there are only a few concepts in Europe that have been realised in the sense of this definition. The main differences to a CDS are that a microgrid can be separated from the superordinate grid (island mode) and can also be used to supply private households (only permitted to a very limited extent with CDS, see Appendix 2).

Figures c) - d) show examples of systems that are connected at higher voltage levels.Most likely the Robinson DER System will be limited to a voltage level below 110 kV.

4.2 Requirements for grid connections

In Europe as well as worldwide, there exists a multitude of nationally/regionally valid standards for the connection of PGM to a superordinate power grid. The rules laid out under RfG NC within the Agency for the Cooperation of Energy Regulators (ACER) Framework Guidelines on Electricity Grid Connection were aimed to meet the principles of the Third Energy Package namely to increase sustainability, security of supply and to elaborate the concept of a single European market for electricity.

[3] The term microgrid is often used as a generic term for private networks, so a precise distinction is necessary here

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Objectives	Establish legally binding EU wide harmonization of grid interconnection requirements	Ensure system security with a growing share of RES and variable generation	Boost the market of generation technologies and increase competitiveness
Approach	Requirements according to the system relevance of the generators	Balance European wide harmonized requirements as well as to take into account regional specifics	Technology-neutral
Implementation	Definition of generator types A/B/C/D with associated requirements	Classification of requirements: - Exhaustive and - Non-exhaustive - Non-mandatory	General requirements for all generators plus additional for - synchronous PGM - Power Park Modules - Offshore PPM

In May 2018, two years after the RfG NC had been published, European Member States have been obliged to conclude the respective national implementations of their individual grid codes.

European member states in this context sublement the twenty-six European member states and following nine other European countries, which belongs to the Eurpoean synchronus grid aera (figure 5): Bosnia and Herzegovina, Switzerland, Montenegro, North Macedonia,Serbia, Great Britain and Northern Ireland, Iceland and Norway (relevant for the Robinson demonstrator project)

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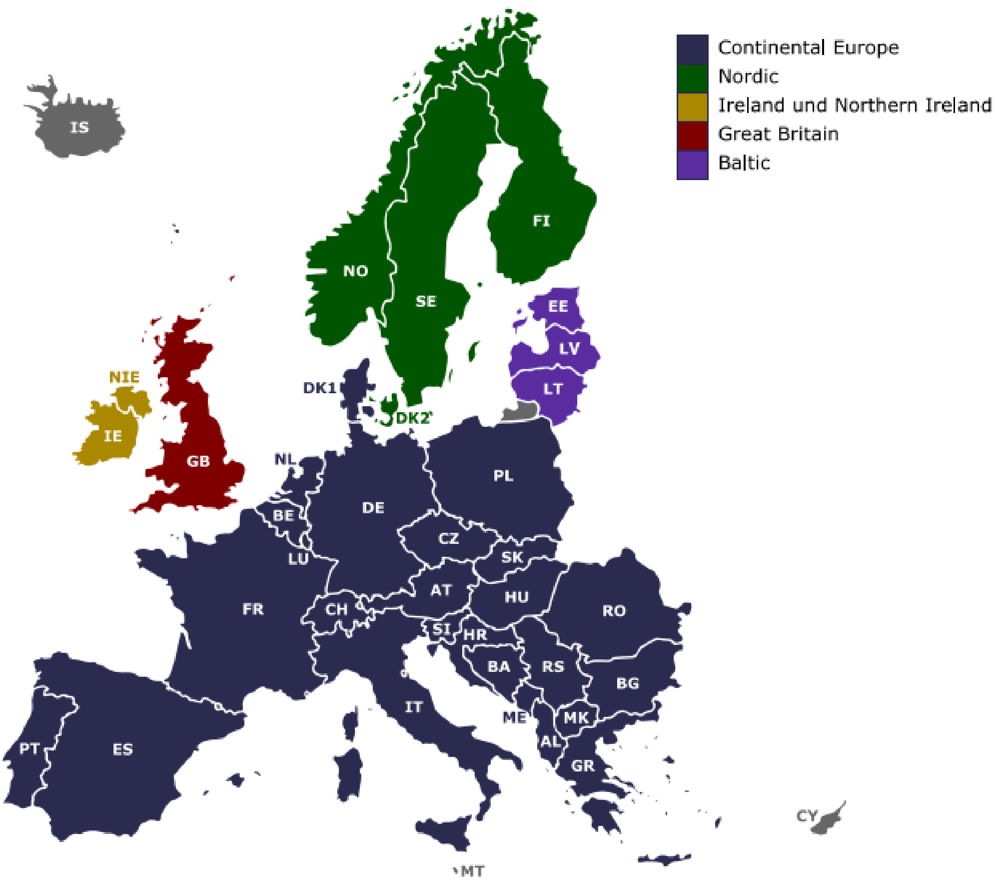

Figure 5 Synchronous areas for European countries

The Energy Community provides documentation for technical assistance for the connection network codes implementation *(Electricity Coordinating Center Ltd. 2021*). In parallel the European Standard *EN 50549-1/2*, prepared by the European Committee for Electrotechnical Standardization (CENELEC) (CLC/TC 8X), relates to both the RfG NC and current technical market needs. Its purpose is to give detailed description of functions to be implemented in products. This European Standard is also intended to serve as a technical reference for the definition of national requirements where the RfG NC requirements allow flexible implementation (mainly for low voltage connection Typ A and B PGMs)[4]. In (*CENELEC & SCHAUPP 2018*) an overview about intention and scope of the EN 50549 is given.

The following table shows the NfG NC requirements for PGM divided in general and sitespecific requirements as well as classified according to different types A-D (definition see below)

[4] Annnex C of EN 50549 provides an overview over all parameters used in this European Standard, the value range and the default values provided in this European Standard as well as a column for specific values as required by one DSO and the responsible party.

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Table 1 RfG NC list of requirements

RfG Article	Requirement	General (G) or site specific (S) decision on introduction at national level	
		Requirement as such	Parameters
6 (3)	Industrial site - conditions for disconnection of generating modules with critical loads	S	S
13 (1) (a) (ii)	wider frequency ranges	S	S
13 (2) (b)	disconnection at randomized frequencies	G	S
13 (2) (f)	minimum regulation level of LFSM-O	S	-
13 (6)	remote control of active power output	S	-
14 (2) (b)	remote control of active power output	S	-
15 (2) (d) (iv)	shorter initial FSM response delay for PGMs without inertia	G	S
15 (5) (a) (ii)	quotation for providing black-start capability	S	G/S
15 (5) (b)	capability of island operation	S	G/S
15 (6) (b) (i)	definition of quality of supply parameters	S	G/S
15 (6) (c) (i)	provision of simulation models	G	S
15 (6) (c) (iv)	recordings of PGM performance	S	G/S
15 (6) (d)	additional devices for secure system operation	S	S
16 (2) (a) (ii)	shorter times of operation for simultaneous low voltage and high frequency	G	S
16 (2) (b)	wider voltage ranges and longer minimum times of operation	S	S
16 (2) (c)	voltage thresholds for automatic disconnection	S	S
17 (2) (a)	reactive power capability for synchronous PGMs	G	S
18 (2) (a)	supplementary reactive power compensation for HV connecting line of synchronous PGMs	G	S
20 (2) (a)	reactive power capability of PPMs	G	S
20 (2) (b)	fast fault current injection by PPMs	G	S
20 (2) (c)	asymmetrical fault current injection by PPMs	G	S
21 (2)	synthetic inertia capability of PPMs	G	S
21 (3) (a)	supplementary reactive power compensation for HV connecting line of PPMs	G	S
21 (3) (f)	power oscillations damping by the power park module	G	S

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Table 2 SPGM and PPM related requirements classified according to PGM type (CENELEC & SCHAUPP 2018)

	Type A	Type B	Type C	Type D
Frequency issues				
Frequency ranges	X	X	X	X
RoCoF withstand capability	X	X	X	X
LFSM-O	X	X	X	X
Admissible active power reduction	X	X	X	X
Logic Interface (1) (remote switch on/off)	X	X		
Automatic connection to the Network	X	X	X	X
Logic Interface (2)		X		
Frequency stability			X	X
Disconnection of load due to underfrequency			X	X
LFSM-U			X	X
FSM			X	X
Frequency restoration control			X	X
Real-Time monitoring of FSM			X	X
Rate of change of active power output			X	X
Instrumentation, simulation models and protection issues				
Control schemes and settings		X	X	X
Electrical protection schemes and settings		X	X	X
Information exchange		X	X	X
Loss of angular stability or loss of control			X	X
Instrumentation			X	X
Simulation models			X	X
Neutral point at the network side of step- up transformer treatment			X	X
Synchronisation			X	X
Angular stability (Capabilities to aid angular stability)				X
System restoration issues				
Reconnection capability		X	X	X
Black start			X	X
Capability of island operation			X	X
Operation following tripping to houseload (quick resynchronization capability)			X	X
Active power recovery		X	X	X
Voltage issues				
Fault Ride Through capability of synchronous generators connected below 110 kV		X	X	
Fault Ride Through capability of synchronous generators connected at 110 kV or above				X
Automatic disconnection due to the voltage level			X	X
Voltage ranges				X
Reactive power capability (simple)		X		
Reactive power capability at maximum active power			X	X
Reactive power capability below maximum active power			X	X
Voltage control system (simple)		X	X	
Voltage control system				X

Based on their voltage level at the connection point and their maximum capacity at generating active power, RfG NC categorizes PGMs into 4 different types:

- connection point voltage below 110 kV and maximum capacity of 0,8 kW or more (type A);
- connection point below 110 kV and maximum capacity at or above a threshold proposed by each relevant TSO in accordance with figure 6 (type B / C / D);
- connection point at 110 kV or above (type D).

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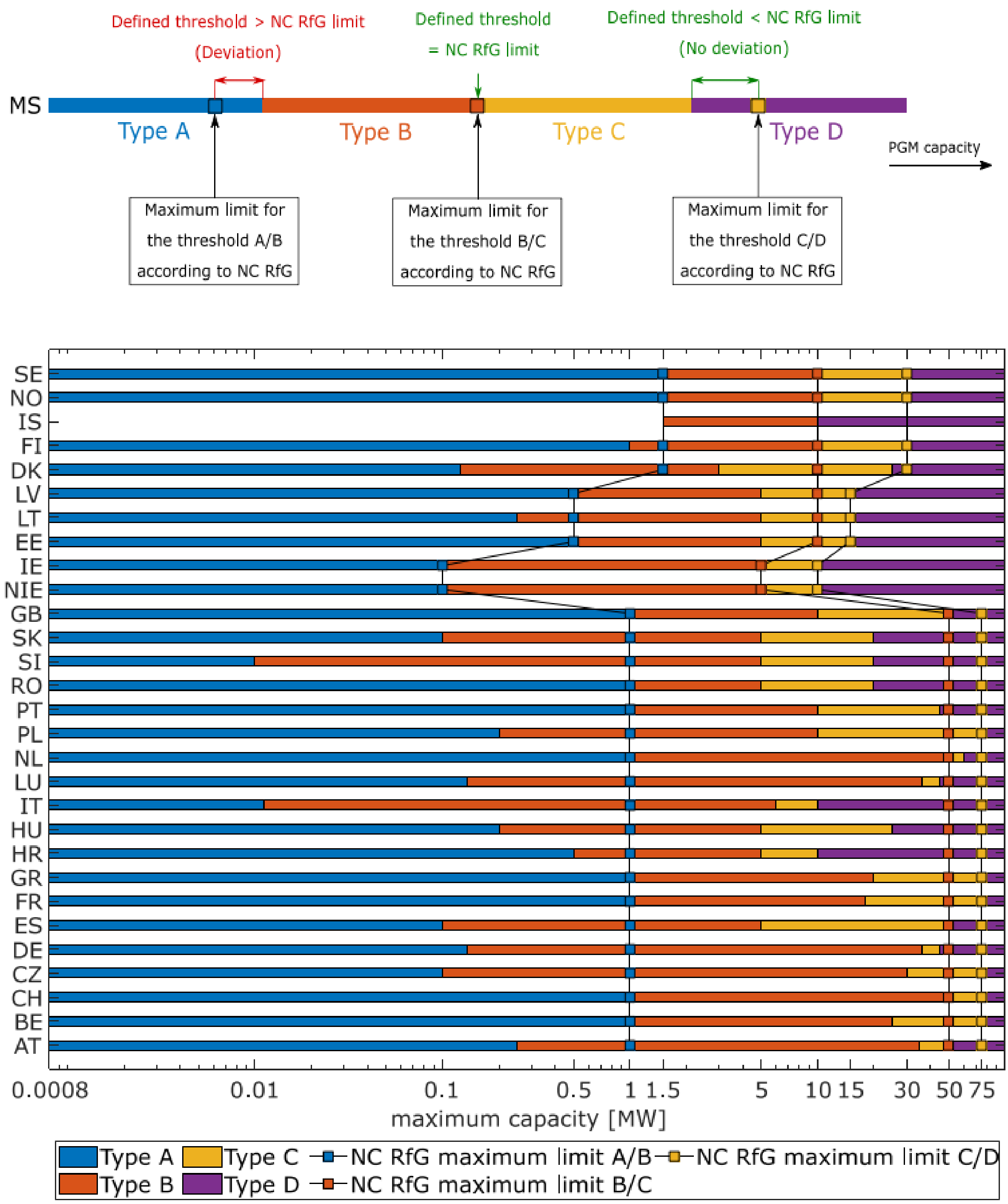

Figure 6 National thresholds for type classification A-D [6]

An essential task of the Member States within the framework of the harmonisation of connection requirements is therefore the classification of the respective connection requirements into these classes.

Figure 6 indicates that the limits for classification into type A and type B are not uniform in the MS+. While the limit between type A and B is 1.5 MW in Norway, it is 1 MW in Greece. This different classification with the resulting requirements to be met (table 2) should be taken into account when

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choosing the component size of the "Robinson system" as well as when designing the energy management system.

DER systems are usually to be assigned to type A to B due to the size of the units. However, in cases where e.g. the connection to a voltage level > 110 kV is necessary, because e.g. no further connection to a lower voltage level is available, the connection conditions according to type D would apply[5]!

In (*Bründlinger 2019*), (*Storage4Grid 2020*), (*ENTSOE & Pfeiffer 2016*), the status quo regarding the national implementation of the EU directive from 2016 are presented. The values for the parameters from the respective national standards are also partly compared (*FGH 2021*).

As a result it is stated that as of October 2019, national requirements have been detailed, but

- Major differences between the countries
- Various levels of details in the national implementation documents
- Official approval still pending in some countries
- High level of uncertainty regarding the implementation, testing and certification…

Robinson focuses on the application of the system for (industrial) consumers on "islands". As already described, this includes not only geographical islands but also "virtual" onshore islands. In the RfG NC, according to Article 3(2) a, electricity generation plants that are connected to grids on islands that are not synchronised with the synchronised grids according to Figure x are exempted from the requirements according to the NfG NC.

For the follower islands explicitly named in Robinson, this currently applies to Crete, as the island is not yet connected to a higher-level (transportation) grid. However, the Greek grid operator IPTO is planning a grid connection to the Greek mainland for 2023. This would mean that Crete would also be subject to the NfG NCs in the future. With regard to the general conditions for the duplication of the Robinson system, it is therefore assumed that a connection of electricity-generating plants is subject to the general conditions of the NfG NCs as well as the conditions further specified in the respective states. In Appendix 1 an overview of the requirements and parameters set by the MS(+) according to NfG NC for type A is given.

However, it is important for DER systems such as the planned Robinson system that, apart from pumped storage systems, no other electricity storage systems such as batteries, which are also planned in principle as electricity storage components for Robinson, are taken into account in the NfG NC. In this case, the connection requirements would have to be clarified with the local grid operators in each individual case, which would then be different for projects at other locations/countries. This situation has been addressed, for example, by establishing working groups such as the expert groups (MSC and Storage) established by the Grid Connection European Stakeholder Committee (GC ESC) (*ENTSOE EC MSC / Storage 2018*).

[5] Each of the generators in the scenario HV network (Figure 4) will at present be classed as Type D due to their connection voltage at the transmission network, being equal to or greater than 110kV (which is the voltage threshold, set within RfG, in terms of Type D).

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As some result, the Expert Group "Storage" suggests, that a Non - Synchronous Electricity Storage Module (as defined above) could be comparable to the same requirements to those of a Power Park Module under RfG NC. Also the BRIDGE initiative[6] adresses the current situtation about the RfG NC and gives recommendations for specific regualtory aspects for island cases and implementation of storage systems (*BRIDGE Regulation Working Group 2018*).

Parallel to the national implementations of the requirement from the EU directive, there is a multitude of other codes in Europe, but also worldwide. In *(Rebollal 2021)* as an result of a comparison of international codes, a clear need to define a common framework for distributed energy resources (DERs) and microgrid standards in the future, wherein topics, terminology, and values are expressed in a manner that may widely cover the entire diversity in a way similar to how it has already been expressed at the network transport level by the ENTSO-E codes, is identified. Special intention is given to the *IEEE 1547-2018*[7] beeing the most complete standard is this respect (but covering 60 Hz grids only). Other standards explicitely covering DER systems connected with the grid are provided by the International Electrotechnical Commission (IEC*) IEC-TS-62786* or *IEC-TS-62898 1/2/3* which is a guideline for microgrid planing/specification/technical requirements/operation and control. Also in Germany the Standard provided bei VDE, *VDE-AR-N 4110:2019* includes requirements about storage as part of the DER system. Recently National Grid Electricity System Operator updated their grid code for Great Britian, which now also includes all types of DER systems (National Grid ESO 2021).

Regarding the current situation for the demo project in Eigerøy, the national implementation of the RfG NC for Norway is available in form of a consultation draft of the NVF (Statnett 2021).

However, the connection conditions according to the RENblad 3xx standard (*REN 2011*) are valid for the grid connection of the planned Robinson PGMs to the local distribution grid of the operator Dalane Energy. The table of contents of the technical connection condition RENblad 303 is listed in Appendix 3. In principle, these are based on EN 50549, but to some extend define their own values for the individual parameters. Whether it is intended to adapt these to the NVF as soon as they become valid could not be clarified during the preparation of this report.

Since all planed PGMs within the Robinson demo project are connected behind the POC to the internal LV grid of the single consumer Prima Protein (according to Figure 4b), many aspects of general DER systems, such as different consumers/owners, different connection points of the PGMs to the electrical grid, use of electricity storage (including the use of electric vehicles as storage and feed-back) do not come into consideration *(Eurelectric 2013), (Scott 2016), (Zia 2018), (Moura 2019), (Smart Electric Power Alliance 2020*). But for the planned transfer of the results of the Eigerøy demo project to the following islands and beyond, for other setups the respective valid framework conditions must be taken into account. The research shows that there will be further harmonisation of standards in the foreseeable future that explicitly include the special features of DER systems like the Robinson one.

[6] BRIDGE is a cooperation group involving Low Carbon Energy (LCE) Smart-Grid and Energy Storage projects funded under the Horizon 2020 program

[7] IEEE 1547 (Standard for Interconnecting Distributed Resources with Electric Power Systems) is a standard of the Institute of Electrical and Electronics Engineers meant to provide a set of criteria and requirements for the interconnection of distributed generation resources into the power grid.

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5. Connection to gas network

Within the Robinson demo project, the different types of gas produced are only transported in the internal network of the single consumer. There is therefore no feed-in to a regional network. Permits must be obtained from the local authorities for the construction and operation of an internal gas distribution network.

Feeding into an existing gas distribution network is regulated differently at national/local level in the various European countries. An example of such regulations is the worksheet G2000 prepared by the DVWG (*DVWG 2017*)in Germany, or the Technical Minimum Requirements (TMA) for the injection of upgraded biogas into a local natural gas network of the operator (*NEW Netz 2019*). These guidelines are primarily concerned with the quality of the injected gas, the use of standardised components and measuring equipment, as well as the recording of the incoming/outgoing volume flows and their documentation and data exchange.

However, similar to ENTSOE for electricity networks, the mission of the Network of Transmission System operators for Gas (ENTSOG 2019) is to facilitate and improve cooperation between national transmission system operators (TSOs) across Europe to ensure the development of a pan-European transmission network in line with the European Union's energy policy objectives.

But it is unlikely that biogas will be fed into transmission networks as part of the implementation of DER systems, as DER systems are about regional exchange/consumption of resources and not about participation in (inter)national trade.

6. Connection to district heating grid

A special feature of the planned Robinson concept is the connection of different DER systems with the different energy grids (electricity/heat/gas). As can be seen from the previous chapter, there are very extensive regulations for the connection to an electricity grid, for which there are efforts for harmonisation at the European level due to transnational connections of the electricity grid. For heating grids, such efforts for harmonisation at the EU level do not exist yet. Therefore, national and regional regulations must be observed. In (*BEIS 2020*) an overview of the situation in some European countries is given (e.g. the UK and Norway). Netherlands and Norway are regulated markets, having a specific government department or regulator that has some level of dedicated responsibility for heat networks. Germany and Finland are largely unregulated although in both cases the Competition Authorities can step in on competition issues. UK and Scottish Governments are both considering regulatory frameworks for heat networks.

There are two types of Heat Network. The first is communal heating, in which all dwellings within a single building are supplied by a central heating system. The second is District Heating, where heat is produced from a central source and delivered through a network to multiple buildings or sites. Buildings could be residential, public or commercial use or some combination of these. In (*Euroheat & Power 2016*) general guidelines which contain a set of recommendations focusing on planning,

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installation, use and maintenance of district heating (DH) substations within district heating systems throughout Europe are given[8].

The following standards and EU directives are basis for this guidelines

- Pressure Equipment Directive (97/23/EC)
- Measuring Instruments Directive (2004/22/EC)
- Energy Performance of Buildings Directive (2002/91/EC)
- Machinery Directive (2006/42/EC)
- Energy Services Directive (2006/32/EC)
- Eco-design Directive (2005/32/EC)
- EN/CEN standards: EN 1434, CEN 311, etc.

As described in (BEIS 2020) Norway operates light touch regulation via a licensing regime (Energy Act) that is administered by a departmental body sitting under the Ministry of Oil and Energy. Mandatory connection, price and planning-type conditions are the main focus of regulation, with some additional scrutiny over security of supply, emergency preparedness and decarbonisation. Chapter 5 of the Norwegian Energy Act regulates the licensing of District Heating plant, mandatory connections and delivery, rates and regulations around shut downs. The Act leaves certain matters to be decided by the Ministry of Oil and Energy such as size thresholds for a license. The current threshold is 10MW. Plant below this size wishing to avail of mandatory connection also need a license. With respect to renewable energy, the licensee must account for renewable share in its annual district heating production in 2019 and 2026. A report shall then be presented showing consumption of different energy products, including quantity consumed biogas and natural gas, which are included in the total heat / energy supply from the plant. For renewable share below 95%, a plan for how the licensee plans to phase out fossil fuels must be submitted. The NVE may, after a specific assessment, impose measures that increase the renewable share in the district heating plant.

The currently valid regulations can be found in the “Regulations on technical requirements for construction works” ("Byggteknisk forskrift - TEK17") (*Norwegian Bulding Authority 2017*). The table of contents in Appendix 4 provides an overview. In contrast to the very detailed proofs for the operation of PGMs on electrical grids, the focus for the connection to heat grids is more on compliance with quality standards for the components used and the installation, safety regulations and effects on the environment[9].

[8] Nevertheless, when national regulations pose rules contrary to those recommended in the guidelines, these regulations should in all cases prevail. For instance,throughout most countries in Europe prescriptions exist in order to avoid risks of diseases like Legionella.

[9] Compare the tables of contents from Annex 3 and 4

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Appendix 1 NfG NC requirements

NFG NC requirements for the Type A size range in which the PGMs in the Eigerøy demo project fall. The values for the exhaustive requirements are shown for the individual MS (+).

Type A exhaustive requirements

- Frequency ranges and minimum time periods for operation
- Resistance to frequency gradients (Rate of Change of Frequency - ROCOF)
- Permissible reduction in the maximum active power output with falling frequency
- Limited Frequency Sensitive Mode - Overfrequency (LFSM-O)
- Definition of Pref for PPMs
- Logic interface for cease of active power
- Automatic connection

And quite detailed

Typ A non exhaustive requirements

- Limited Frequency Sensitive Mode - Underfrequency (LFSM-U)
- Voltage related active power reduction (P(U))
- Frequency related protection
- Voltage ranges and minimum periods for operation
- Voltage related protection
- U-Q/Pmax for SPGMs / PPMs
- P-Q/Pmax for SPGMs / PPMs
- Reactive power control
- Power quality
- LVRT for SPGM / PPM
- Over Voltage Ride Through (OVRT)
- Vector shift
- Zero current mode for PPM technology
- Active power recovery after fault
- Reconnection/synchronization requirements after disconnection
- Unintentional/Intentional Islanding operation
- Uninterruptible Power Supply (UPS)
- Information exchange

The following is a sampling of the (exclusive) requirements for Typ A (and above) as defined by the MS+ (*FGH 2021*). The intention is to show the status of harmonisation between the MS(+) since this already reflects possible impact on the design of the Robinson system in various European countries.

Frequency ranges and minimum time periods for operation

The minimum period for operation depends on the synchronous area to which the respective country belongs. The values highlighted (beige) above are non-exhaustive parameters and shall be set by each MS+ at the national level. The other values are fixed and regarded as exhaustive parameters. For the frequency range FR2, a minimum operating time must be specified in each country. For the Baltic States and the states of the Continental European interconnection system, the specified time period shall not be shorter than that defined for the FR1 area.

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Table 3 Definition of frequncy ranges and minimum time periods for operation according to the RfG NC

Frequency range	FR0	FR1	FR2	FR3	FR4	FR5
from [Hz]	47	47.5	48.5	49	51	51.5
to [Hz]	47.5	48.5	49	51	51.5	52

		Frequency range					
		FR0	FR1	FR2	FR3	FR4	FR5
Minimum time period [min]	Continental Europe	n/a	≥30	$\geq t_{FR1}$	∞	30	n/a
	Great Britain	1/3	90	≥90	∞	90	15
	Ireland and Northern Ireland	n/a	90	≥90	∞	90	n/a
	Baltic	n/a	≥30	$\geq t_{FR1}$	∞	≥30	n/a
	Nordic	n/a	30	≥30	∞	30	n/a

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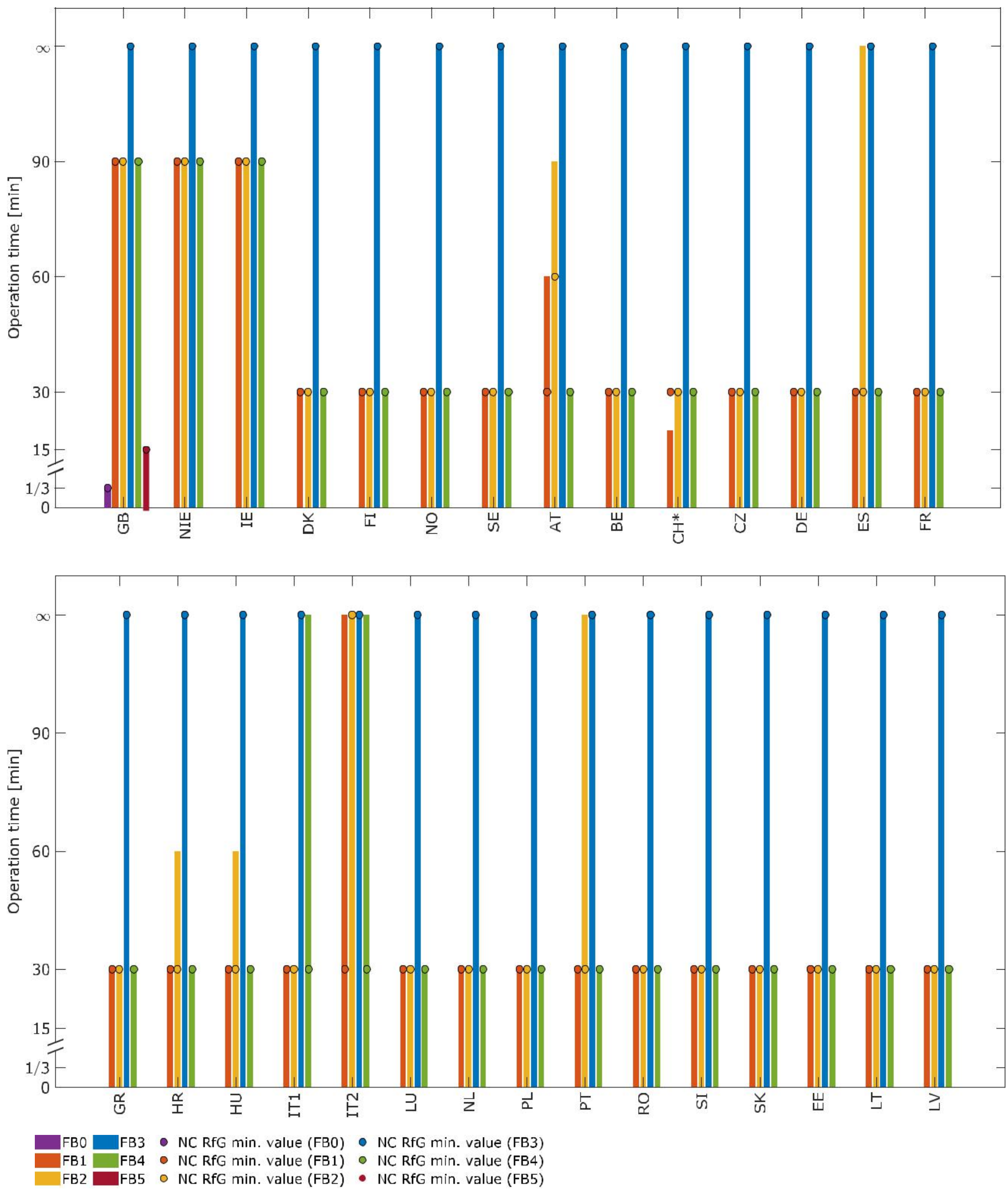

Figure 7 Minimum operating periods [6]

Rate of change of frequency (ROCOF) immunity

A PGM of type A and above must be able to maintain connection to the network and operation in case of frequency gradients up to a certain value in accordance with Article 13 (1) (b) of RfG NC, unless the disconnection from the network was the consequence of the tripping of the power failure protection caused by frequency changes.

The generating modules in a generating plant shall have ROCOF immunity for a ROCOF equal or exceeding the value specified by the responsible party. If no ROCOF immunity value is specified, the following ROCOF immunity shall apply, making distinction between generating technologies:

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- Non-synchronous generating technology: at least 2 Hz/s
- Synchronous generating technology: at least 1 Hz/s

The ROCOF immunity is defined with a sliding measurement window of 500 ms.

Accros MS+ states the values set varies between 0.5 Hz/s and 2.5 Hz/s, some states do not use (yet) this parameter.

Table 4 Distribution of the maximum frequency gradient (+/-) with the corresponding sliding window (SW)

Value [Hz/s]	MS+	Number of MS+	Comments
0,5 (n/a for SW)	IS*	1	* Defined for type B and D
1 (for 0,5s)	GB, NIE, IE, 50549*	3	* EN 50549-1/-2, here SPGM
1,5 (for 1s)	NO	1	
2 (n/a for SW)	AT, DK	2	
2 (for 0,5s)	CZ, ES, HR, HU*, PL, SI, SK, FI, SE, PT, 50549**	10	* Defined for type B, C and D ** EN 50549-1/-2, here non-SPGM
2,5 (n/a for SW)	EE	1	
2,5 (for 0,5s)	HU*, LT, LV	3	* Defined for type A
2,5 (for 0,1s until 1s)	IT	1	
1,25 (for 2s) or 1,5 (for 1s) or 2 (for 0,5s)	DE, LU, NL, RO	4	
Over - and underfrequency profile	BE, GR	2	
n/a	CY, BA, BG, CH, FR, ME, MK, RS	8	

Permissible reduction in the maximum active power output with falling frequency

A permissible reduction in the maximum active power output with falling frequency is to be set in accordance with Article 13 (4) for PGMs of types A to D. The active power reduction is defined as a reduction gradient that shall lie within predefined limits. The lower limit corresponds to a reduction by 2% of the maximum capacity (Pmax) per frequency drop of 1 Hz below a frequency of 49 Hz. The upper limit corresponds to a reduction by 10% of the maximum capacity per frequency drop of 1 Hz below a frequency of 49.5 Hz.

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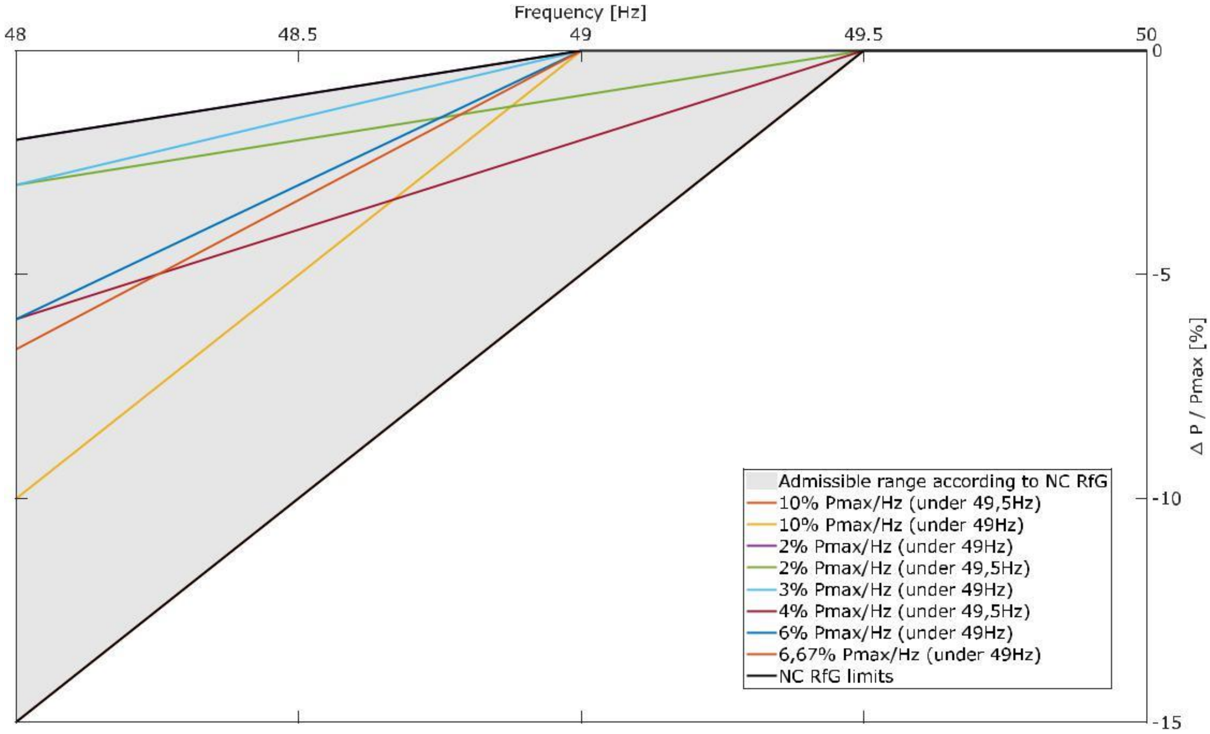

Figure 8 Different threshholds of the MS+ for the allowable reduction in the maximum active power output with falling frequency [6]

Figure 8 shows that all MS+ define values, which are within the boundaries, set by the NfG NC, but nevertheless there are some differences, to which the systems need to be adjusted for most countries.

Limited Frequency Sensitive Mode - Overfrequency (LFSM-O)

The requirements for the limited frequency sensitive mode - overfrequency (LFSM-O) for PGMs of types A or above must be defined in accordance with Article 13 (2) of RfG NC in terms of the frequency threshold and the droop. While the frequency threshold must be between 50.2 Hz and 50.5 Hz, the droop must be selected between 2% and 12%. Since the LFSM-O is about a frequency sensitive reduction in the active power output, a certain behavior of the PGM may be required when the minimum regulating level, i.e. the minimum power for regular operation is reached. Two actions are possible: Either the PGM must continue operating at this value or the active power must be further reduced.

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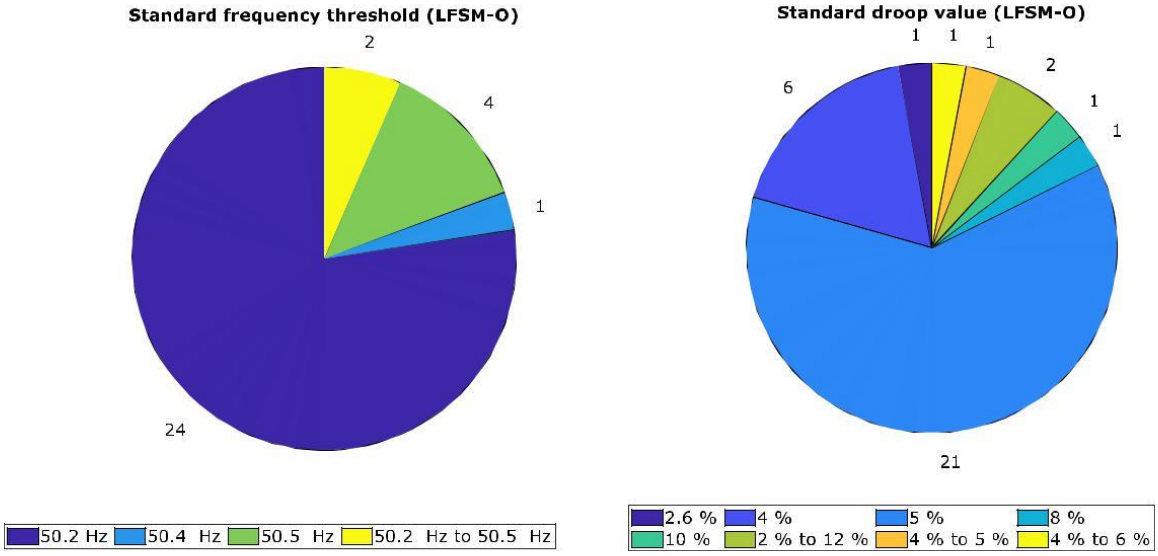

Figure 9 Distribution of the standard / fixed values for the frequency threshold and droops for the LFSM-O

Reference active power definition Pref for PPMs

When implementing the frequency sensitive mode (FSM) or the limited frequency sensitive modes (LFSM-O and LFSM-U) for PPMs, the TSO shall specify a reference power to which the requested droop is related to (in order to derive a nominal power reduction). This parameter can be either:

- The Maximum Capacity of the generator (Pmax) or
- The actual active power at the moment of entering into LFSM or FSM operation by passing the frequency threshold (Pmom).

Table 5 Distribution of the reference active power definition (Pref) for LFSM and FSM for PPMs [6]

Definition	MS+	Number of MS+
Reference active power (Pref) for LFSM and FSM for PPMs		
Maximum Power Capacity (Pmax)	ES, GR, HR, HU, PL, PT, RO, SI, GB, NIE, IE, EE, LT, DK, FI, IS, NO, SE	18
Actual active power output at the time of reaching the threshold value (Pmom)	AT, BE, CH, DE, FR, IT, LU, NL, EN 50549-1/-2	8
Defined by the System Operator	CZ, SK, LV	3
n/a	CY, BA, BG, ME, MK, RS	6

Logic interface for cease of active power

PGMs of type A and above must have the capability to case active power within 5 seconds using an interface (input port) as stated in Article 13 (6) of RfG NC.

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Implementation	MS+	Number of MS+	Comments
Type A	AT, BE, CZ, DE, FR, GR, IT, NL, PL*, RO, SI, IE, NIE, LT*, DK, FI, NO**, GB, LU	19	* Cease within 5 sec not mentioned explicitly **In general required for units above 0.1 MW
n/a	CY, BA, BG, ME, MK, RS, CH, EE, ES, HR, HU, IS, LV, PT, SE, SK	16	

Figure 10 Distribution of the MS+ based on the capability of PGMs to cease active power using a logic interface [6]

Appendix 2 Closed Distribution System (CDS)

Category: European Union Electricity Market Glossary

Published: 08 May 2015

Last Updated: 12 May 2021

Closed distribution system (CDS) is a network classified as closed distribution system pursuant to Article 28(1) of Directive 2009/72/EC at national level.

'Closed distribution system' means a system classified pursuant to Article 28 of Directive 2009/72/EC as a closed distribution system by national regulatory authorities or by other competent authorities, where so provided by the Member State, which distributes electricity within a geographically confined industrial, commercial or shared services site and does not supply household customers, without prejudice to incidental use by a small number of households located within the area served by the system and with employment or similar associations with the owner of the system.

Article 2(5) of the Demand Connection Code (DCC)

Article 28 of Directive 2009/72/EC defines such a network as a system which distributes electricity within a geographically confined, industrial, commercial or shared services site and does not (without prejudice to a small number of households located within the area served by the system and with employment or similar associations with the owner of the system) supply households customers.

The closed distribution network will either have its operations or the production process of the users of the system integrated for specific or technical reasons or distribute electricity primarily to the owner or operator of the closed distribution network or their related undertakings.

The provisions on CDSs, as laid down in Article 28 of the Electricity Directive, are maintained in Article 38 of the Recast Electricity Directive.

The Winter Energy Package adds, however, the clarification that closed distribution systems must be considered distribution systems (Article 38(2) of the Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU)..

As the consequence of this addition, closed distribution networks will need to comply with the unbundling rules applying to distribution system operators (save for the exemption under the “100,000-customers”- rule in respect to small isolated systems, which remained unchanged from the 3rd Package provisions, which would be applicable and applied by the Member State concerned).

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Furthermore, three new exemption possibilities for the EU Member States with regard to closed distribution networks have been added in the Directive (EU) 2019/944 - Member States may provide for National Regulatory Authorities (NRAs) to exempt the Closed Distribution Network Operator (CDSO) from the following requirements:

- to procure flexibility services and to submit network development plans to the NRA;
- not to own, develop, manage or operate recharging points for electric vehicles;
- not to own, develop, manage or operate energy storage facilities.

In addition, the new Citizen Energy Communities (CECs) can also become a closed distribution network under Article 38 of the Directive (EU) 2019/944.

Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU, Article 38, Recitals 47, 66

Recital 47

This Directive empowers Member States to allow citizen energy communities to become distribution system operators either under the general regime or as 'closed distribution system operators'. Once a citizen energy community is granted the status of a distribution system operator, it should be treated as, and be subject to the same obligations as, a distribution system operator. The provisions of this Directive on citizen energy communities only clarify aspects of distribution system operation that are likely to be relevant for citizen energy communities, while other aspects of distribution system operation apply in accordance with the rules relating to distribution system operators.

Recital 66

Where a closed distribution system is used to ensure the optimal efficiency of an integrated supply that requires specific operational standards, or where a closed distribution system is maintained primarily for the use of the owner of the system, it should be possible to exempt the distribution system operator from obligations which would constitute an unnecessary administrative burden because of the particular nature of the relationship between the distribution system operator and the system users. Industrial sites, commercial sites or shared services sites such as train station buildings, airports, hospitals, large camping sites with integrated facilities, and chemical industry sites can include closed distribution systems because of the specialised nature of their operations.

Article 38
Closed distribution systems

1. Member States may provide for regulatory authorities or other competent authorities to classify a system which distributes electricity within a geographically confined industrial, commercial or shared services site and does not, without prejudice to paragraph 4, supply household customers, as a closed distribution system if:

(a) for specific technical or safety reasons, the operations or the production process of the users of that system are integrated; or

(b) that system distributes electricity primarily to the owner or operator of the system or their related undertakings.

2. Closed distribution systems shall be considered to be distribution systems for the purposes of this Directive. Member States may provide for regulatory authorities to exempt the operator of a closed distribution system from:

(a) the requirement under Article 31(5) and (7) to procure the energy it uses to cover energy losses and the non-frequency ancillary services in its system in accordance with transparent, non-discriminatory and market-based procedures;

(b) the requirement under Article 6(1) that tariffs, or the methodologies underlying their calculation, are approved in accordance with Article 59(1) prior to their entry into force;

(c) the requirements under Article 32(1) to procure flexibility services and under Article 32(3) to develop the operator's system on the basis of network development plans;

(d) the requirement under Article 33(2) not to own, develop, manage or operate recharging points for electric vehicles; and

(e) the requirement under Article 36(1) not to own, develop, manage or operate energy storage facilities.

3. Where an exemption is granted under paragraph 2, the applicable tariffs, or the methodologies underlying their calculation, shall be reviewed and approved in accordance with Article 59(1) upon request by a user of the closed distribution system.

4. Incidental use by a small number of households with employment or similar associations with the owner of the distribution system and located within the area served by a closed distribution system shall not preclude an exemption under paragraph 2 being granted.

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Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC, Article 28(1), Recital 30

Article 28

Closed distribution systems

1. Member States may provide for national regulatory authorities or other competent authorities to classify a system which distributes electricity within a geographically confined industrial, commercial or shared services site and does not, without prejudice to paragraph 4, supply household customers, as a closed distribution system if:

(a) for specific technical or safety reasons, the operations or the production process of the users of that system are integrated; or

(b) that system distributes electricity primarily to the owner or operator of the system or their related undertakings.

2. Member States may provide for national regulatory authorities to exempt the operator of a closed distribution system from:

(a) the requirement under Article 25(5) to procure the energy it uses to cover energy losses and reserve capacity in its system according to transparent, non-discriminatory and market based procedures;

(b) the requirement under Article 32(1) that tariffs, or the methodologies underlying their calculation, are approved prior to their entry into force in accordance with Article 37.

3. Where an exemption is granted under paragraph 2, the applicable tariffs, or the methodologies underlying their calculation, shall be reviewed and approved in accordance with Article 37 upon request by a user of the closed distribution system.

4. Incidental use by a small number of households with employment or similar associations with the owner of the distribution system and located within the area served by a closed distribution system shall not preclude an exemption under paragraph 2 being granted.

Recital 30

Where a closed distribution system is used to ensure the optimal efficiency of an integrated energy supply requiring specific operational standards, or a closed distribution system is maintained primarily for the use of the owner of the system, it should be possible to exempt the distribution system operator from obligations which would constitute an unnecessary administrative burden because of the particular nature of the relationship between the distribution system operator and the users of the system. Industrial, commercial or shared services sites such as train station buildings, airports, hospitals, large camping sites with integrated facilities or chemical industry sites can include closed distribution systems because of the specialised nature of their operations.

Appendix 3 Dalane Energie Technical functional requirements

RASJONELL ELEKTRISK NETTVIRKSOMHET

Standard 303

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Appendix 4 TK17 Norwegian Regulations on technical requirements for construction works

Content

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