Submission Document

Design of the System Defence Plan for Ireland

In accordance with the requirements of Articles 11 and 4.5 of the Commission Regulation (EU) 2017/2196 Establishing a network code on electricity emergency and restoration

16th October 2020

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EIRGRID

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1. Abbreviations

- BASA – Balancing and Ancillary Services Agreement
- BMPS – Balancing Market Principles Statement
- CDGU – Centrally Dispatched Generation Unit
- CRU – Commission for the Regulation of Utilities
- DCC – Demand Connection Code
- DSO – Distribution System Operator
- EA – Emergency Assistance
- EAS – European Awareness System
- EMS – Energy Monitoring System
- EWIC – East-West Interconnector
- FCR – Frequency Containment Reserve
- FRR – Frequency Restoration Reserve
- FSM – Frequency Sensitive Mode
- GC – Grid Code
- HVDC – High Voltage Direct Current
- LFCAOA - Load Frequency Control Area Operational Agreement
- LFCBOA - Load Frequency Control Block Operational Arrangement
- LFDD – Low Frequency Demand Disconnection
- LFSM- Limited Frequency Sensitive Mode
- MEC – Maximum Export Capacity
- MVAr – Mega Volt-Ampere reactive
- NCER – Network Code for Emergency Restoration
- NCC – National Control Centre
- OFGS – Over Frequency Generation Shedding
- OSS - Operating Security Standards
- PLC - Programmable Logic Controller
- POR – Primary Operating Reserve
- PPM – Power Park Module
- RfG – Requirements for Generators
- RTC – Real Time Commitment
- RTD – Real Time Dispatch
- RR – Replacement Reserve

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- SAOA – Synchronous Area Operational Agreement
- SCADA - Supervisory Control and Data Acquisition
- SDP – System Defence Plan
- SGU - Significant Grid User
- SOGL – System Operator Guideline
- SONI - System Operator Northern Ireland
- SOR – Secondary Operating Reserve
- SRP – System Restoration Plan
- SVC – Static Variable Compensator
- TOR – Tertiary Operating Reserve
- TSO – Transmission System Operation
- UF – Under Frequency
- UV – Under Voltage
- UVLS – Under Voltage Load Shedding
- WSAT - Wind Stability Assessment Tool

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2. Purpose

This System Defence Plan (SDP) is prepared in accordance with COMMISSION REGULATION (EU) 2017/2196 of 24 November 2017 "establishing a network code on electricity emergency and restoration"[1] (referred to as NCER), which came into force on the 18th of December 2017. Under NCER the Transmission System Operators (TSO) of a member state is required to develop and consult on a SDP prior to submission to the relevant regulatory authority for notification. This is a revised version of the SDP following a previous submission to the Commission for Regulation of Utilities (CRU).

This SDP has been designed based on the requirements detailed within Articles 11 to 22 within NCER, the high-level requirements of these articles include:

- Design of the SDP
- Implementation of the SDP
- Activation of the SDP
- Measures of the SDP

In addition to the SDP providing an overview of the power system defence actions and schemes available to EirGrid as the TSO and the Distribution System Operator (DSO); it also outlines the roles and responsibilities of Significant Grid Users (SGUs) including defence service providers during the implementation of the SDP.

This document also outlines how the system defence measures and procedures that are implemented within the EirGrid TSO controlled area of Ireland relate to the relevant articles of NCER and the Grid Code[2], whilst providing the reader with an:

- Introduction to the system states of the power system
- Introduction to power system operation
- Overview of the system defence services
- Understanding of the roles and responsibilities of specific parties

This is not an operational document to be used by the TSO in the event an Emergency state being declared. The step by step actions used by EirGrid National Control Centre (NCC) are included in real-time operational procedures. While the NCER requirements and licence requirements for system defence are jurisdictional the aim is to ensure the all-island system is maintained in a secure manner, hence there is a separate but complementary Northern Ireland SDP which SONI has developed.

[1] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017R2196&from=en

[2] http://www.eirgridgroup.com/site-files/library/EirGrid/Grid-Code.pdf

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3. Introduction

There are various statutory obligations to which a TSO must adhere from European directives, through to the applicable codes. The hierarchy order is illustrated in Figure 1 below.

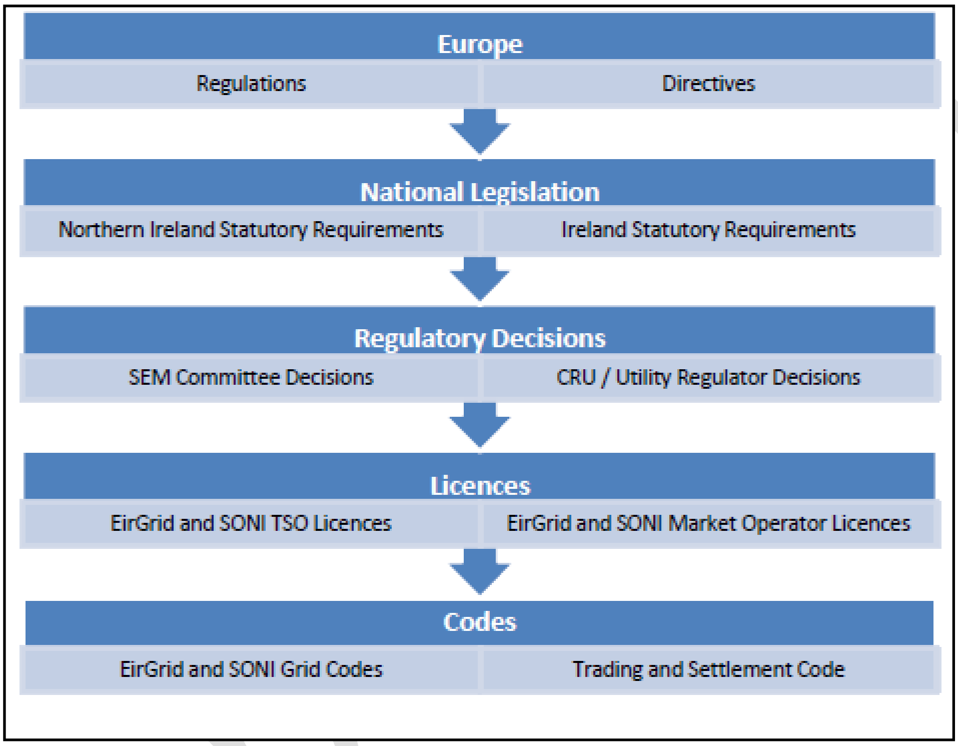

Figure 1 – Hierarchy of Regulations (for illustrative purposes only)

NCER is one of a suite of European Network Codes and Guidelines that seek to achieve a fully functioning and interconnected energy market to ensure the security of supply and to benefit all consumers via competitive markets across the EU.

The NCER aims to establish a set of common minimum requirements and principles for the measures and procedures of TSOs, DSOs and SGUs when a power system is in Emergency, Blackout or Restoration state, however, this SDP concentrates on operating the power system when in Emergency state. There is a separate companion document, the System Restoration Plan (SRP) detailing the TSO response to a Blackout state.

The NCER links and interacts with a number of other Network Codes, including but not limited to:

- System Operation Guideline (SOGL), EU Regulation 2017/1485[3]
- Requirements for Generators (RfG), EU Regulation 2016/631[4]
- High Voltage Direct Current (HVDC), EU regulation 2016/1447[5]
- Demand Connection Code (DCC), EU Regulation 2016/1388[6]

From Figure 1, EU Regulations supersede national legislation and have primacy over national and other regulations. Specifically, the design of this SDP is compiled in accordance with NCER Article 11 and is consulted upon in accordance with Article 7. The SDP includes a list of measures to help prevent the emergency event moving towards a full or partial blackout. By identifying the relevant SGUs responsible for the implementation of measures related to the SDP, known as defence service providers, a mapping table of the SGU category groups, e.g. types of generators, demand, Interconnectors or aggregators, listed against the relevant measure is provided for transparency.

The SDP provides useful background information into how the TSO and DSO operate the system during an Emergency state in order to return to Normal state as soon as practicable. In order to place the SDP in an operational context, there is a description in section 3 on how the TSO and DSO operate the system in the Normal and Alert states. This design of a SDP also provides an overview of how the system defence measures as specified in NCER will be satisfied, including by reference to existing codes.

The first version of the SDP proposal was consulted on from the 14th November 2018 to 12th December 2018 and received no responses. On 18th December 2018, EirGrid submitted the following proposals relating to the SDP to the Commission for Regulation of Utilities (CRU):

a) Terms and conditions to act as a defence service provider
b) List of Significant grid users Ireland (the TSO stated there are no High priority grid users so did not provide a list)
c) Design of the System Defence Plan

Documents a) and b) are required to be approved by the CRU while the design of the SDP is only required to be notified to the CRU. However, the SDP strongly interacts with the NCER documents that do require approval and should be considered together as a

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[3] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016R1388&from=EN

[4] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016R0631&from=EN

[5] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016R1447&from=EN

[6] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016R1388&from=EN

package. On the 2nd September 2019, the CRU published a decision to not approve documents a) and b) above and seek amendments to all the documents submitted by EirGrid. While the Design of the SDP is not subject to formal approval, the CRU provided informal comments, as the CRU noted that the SDP is critically important to system operation and appropriate procurement of defence service providers. In addition to meeting the SDP requirements as stipulated in NCER, this document has close regard for CRU feedback in this revised SDP. Additionally, the document has been updated in collaboration with the DSO.

The following public documents, which have arisen from the requirements of SOGL also relate to NCER. All, except the Operating Security Standards, had not been written at the time of the original submission to the CRU and are now of relevance to this resubmission proposal.

- Synchronous Area Operational Agreement (SAOA)[7]
- Load Frequency Control Block Operational Arrangement (LFCBOA)[8]
- Load Frequency Control Area Operational Agreement (LFCAOA)[9]
- Business Procedure mapping SOGL System states[10]
- Operating Security Standards (OSS)[11]

EirGrid held a second consultation on our revised proposed Design of the System Defence Plan for Ireland. This consultation opened on 8 July 2020 for an extended period of 6 weeks until 21 August 2020. It was available to download on the EirGrid Group and ESBN websites and was discussed at the All Island Forum on 12 August 2020.

EirGrid (TSO) and ESBN (DSO) received no submissions on the consultations.

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7 http://www.eirgridgroup.com/site-files/library/EirGrid/SAOA-for-the-Ireland-and-Northern-Ireland-Synchronous-area-V2.0-(for-consultation-post-RfA).pdf

8 http://www.eirgridgroup.com/site-files/library/EirGrid/S2-LFC-Block-Operational-Agreement-for-Ireland-and-Northern-Ireland-16.12.2019-(post-Title-2-approval).pdf

9 http://www.eirgridgroup.com/site-files/library/EirGrid/S3-LFC-Area-Operational-Agreement-for-Ireland-and-Northern-Ireland-16.12.2019.pdf

10 https://www.sem-o.com/documents/general-publications/BP_SO_09.2-Declaration-of-System-Alerts.pdf

11 http://www.eirgridgroup.com/site-files/library/EirGrid/Operating-Security-Standards-December-2011.pdf

3.1. Introduction to System States

The TSO is required to monitor and communicate the state of Ireland's transmission systems. The SOGL defines the following five system states (demonstrated in

Figure 2, contained within the red dashed line) and provides a set of criteria for each system state. These system states have been aligned with the existing system alerts in an all-island business process which describes how the system alerts states are defined and declared, BP_SO_9.2[12] refers:

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[12] https://www.sem-o.com/publications/tso-responsibilities/

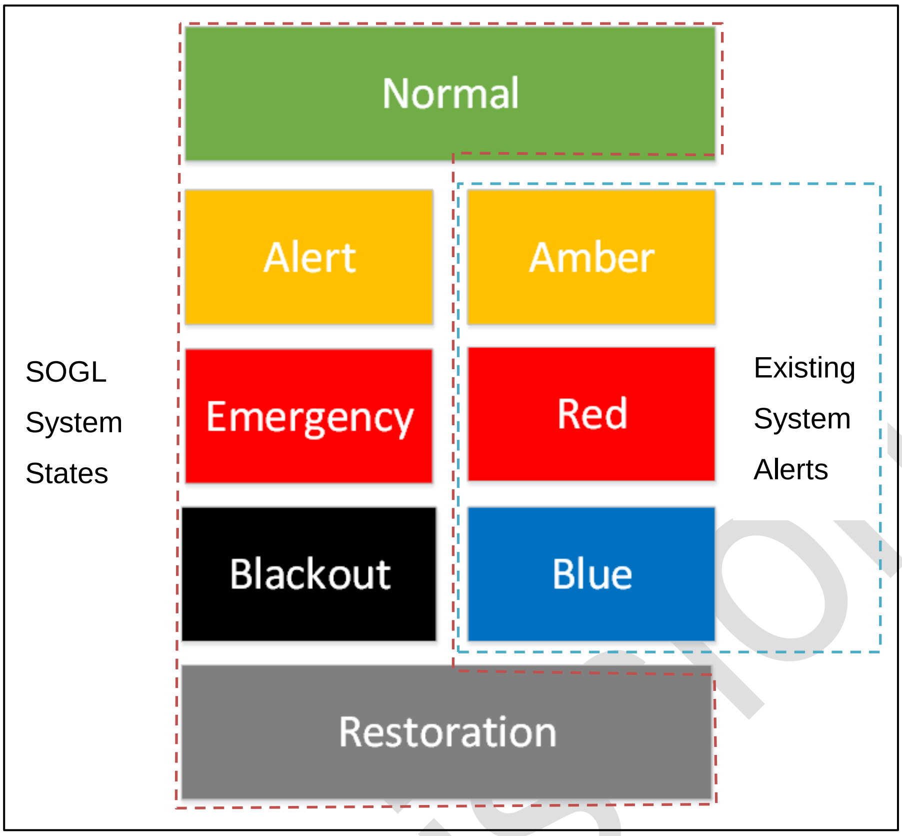

Figure 2 – SOGL aligned System States and Alerts

The system states range from the Normal state to increasing levels of system stress; Alert state (Amber alert); Emergency state (Red Alert); Blackout state (Blue Alert)> There is also a Restoration state during which actions are being taken to bring the power system back to the Normal state.

In accordance with the NCER, the SDP describes the management of the system during the Emergency state or if it is about to enter the Emergency state; therefore to fully explore the system operation during an Emergency state, consideration is given in this SDP to explaining system operation during both Normal and Alert states.

For operation during a Blackout state please refer to the separate companion document the SRP, which is also produced by EirGrid in accordance with NCER.

The classification of transmission system states is prescribed in SOGL article 18 and specifically for EirGrid's transmission system is laid out in BP_SO_9.2[13], which considers the transmission system to be in Emergency state (Red Alert) if any of the following has occurred:

13 https://www.sem-o.com/publications/tso-responsibilities/

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a) there is at least one violation of voltage limits, short-circuit current limits, or current limits in terms of thermal rating;

b) frequency does not meet the criteria for the Normal state or Alert state;

c) any of the following system defence plan measures are activated;

    1. Activation of Under Frequency (UF) load shedding,
    2. Widespread (multiple station) Under Voltage (UV) load shedding,
    3. Activation of system separation protection.
    4. Activation of Emergency Assistance / Emergency Instruction

d) there is a failure in the functioning of

    1. EMS/ SCADA
    2. Phones (Corporate and Optel)

    resulting in the unavailability of those tools, means and facilities for longer than 30 minutes.

The "Red Alert" signal should also be initiated by the TSO when it is likely/ imminent that in the period immediately ahead (i.e. in the next 4 hours) there is a high risk of failing to meet System Demand.

When an Emergency state occurs a Red Alert is issued from the TSO notifying all generating stations, designated transmission stations, DSO, relevant TSO Staff and key external stakeholders. The TSO will also update the European Awareness System (EAS), which notifies other European TSOs that EirGrid is in Emergency state. Once a measure or measures in the SDP have been activated the EAS is updated to Restoration state. Once the system has over an hour of stable operation with a low risk of further alerts, then the Red Alert is cancelled and the TSO updates the EAS to Normal state.

3.2. Generic Power System Operation Overview

Managing a synchronised power system is a complex job and requires co-ordination and co-operation between TSOs, DSOs, generators and demand service providers. While the definition of the three system states Normal, Alert and Emergency are relatively clear, the actions of the TSO are not so distinct. It should be noted that the transition from Normal/Alert state to Emergency state does not convey additional powers on the TSO; the main aim of the TSO remains the same, i.e. to operate, or if necessary restore the system within the operational limits (Normal state).

To maintain the system within operational limits requires constant vigilance; using forecasts and reviewing real-time data to inform the next TSO action to be taken. Due to the small size of the synchronous power island there are relatively many more balancing

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actions to be instructed in comparison to the central EU synchronous system. A prudent TSO does not hold back in taking an action, such as waiting until the system is in Emergency state would be too late and at odds with the TSO's legal mandate. There are, however, some automatic system defence measures described in this SDP to prevent fast acting phenomena.

Therefore, this SDP includes an explanation how the TSO manages within normal operational limits, as some of these measures which are used in Normal and Alert state are still active and continuing if the system fails to recover and transitions to Emergency state.

This SDP will provide a comprehensive overview of how the TSO manages the system against the main events that impact the operation of a synchronous electrical system together with the actions available to the TSO. Where the action is only applied during the defined Emergency state, and hence is a system defence measure, this will be highlighted.

3.3. Operational Limits

There are many variables in a complex synchronous electrical system and the TSO operates within certain limits to ensure standards are maintained. These limits are defined in SOGL and will be enacted in the Operational Security Standards (OSS), which is currently under review to ensure they align with the requirements of the SOGL.

The transmission system is operated so that under normal operation and in the event of certain anticipated contingencies (loss of any single item of generation or transmission plant (N-G, or N-1) there will be no:

- Loss of supply, subject to certain exceptions, see below
- Frequency event outside the operational limits
- Voltage conditions outside the operational limits
- Transmission plant operating outside its short term rating
- System instability

A brief discussion of each of these issues is provided below.

3.3.1. Loss of supply

The transmission system is designed with certain amount of redundancy of plant, e.g. double overhead line circuits and more than a single transformer at a substation. This is to ensure maintenance of an individual item is possible without a subsequent loss of supply. In addition, credible contingencies (fault or forced outages) may be covered

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during planned scheduled maintenance. Therefore, no loss of supply is allowed for a single contingency / maintenance outage, however, a fault during a maintenance outage can lead to a load of up to 80MW to be lost, see OSS for details.

3.3.2. System Frequency

Frequency is a measure of the transmission system being in balance, i.e. when the amount of generation dispatched equals the amount of demand on the system then frequency is exactly 50Hz across the whole synchronous area. Minute by minute variations on the system means that frequency varies from the nominal 50Hz, e.g. an excess of generation and the frequency rises above 50Hz. Therefore, an operating range around 50Hz defines the frequency quality parameters which apply to EirGrid/ SONI synchronous area.

standard frequency range	± 200 mHz
maximum instantaneous frequency deviation	1000 mHz
maximum steady-state frequency deviation	500 mHz
time to recover frequency	1 minute
frequency recovery range	± 500 mHz
time to restore frequency	15 minutes
frequency restoration range	± 200 mHz
alert state trigger time	10 minutes

Table 1 – SOGL Frequency Parameters

Table 1 shows the SOGL defined quality parameters copied from SAOA. The following graphic, Figure 3, summarises when an alert would be triggered based on a deviation from 50Hz for steady state situations (> 1 minute). For clarity, the graphic does show a short duration transient state for one minute where the frequency could fall to 49.0Hz and recover to 49.5Hz and the system remains in Normal state.

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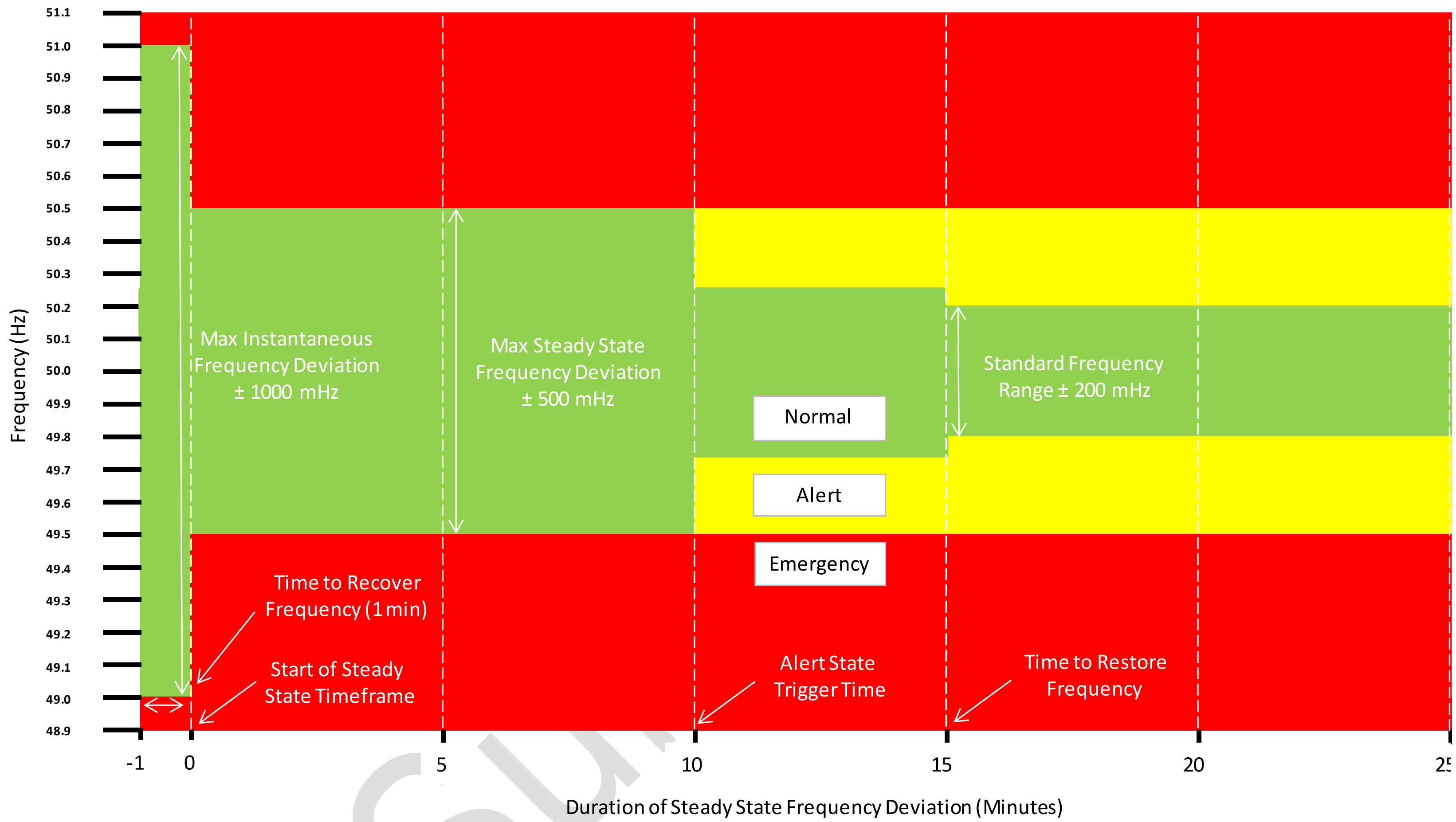

Figure 3 – System States during a Frequency Transient

3.3.3. Voltage

Voltage can be used as an indicator of the health of a transmission system. There are various levels of nominal voltage used in the EirGrid transmission system, 400kV, 220kV and 110kV, plus 275kV on the tie-line to SONI. For efficiency, the higher voltages are used for transmission purposes and the voltage is incrementally stepped down for the DSO to distribute to consumers at lower voltages. Transmission plant is designed to operate at a range centred on the nominal voltage and SOGL provides the following limits (Table 2) for an intact system (Base Case) and for the credible contingencies mentioned above. Voltage issues are more likely to manifest in a localised areas of the transmission system due to individual faults, however, widespread voltage collapse is possible if reactive power (MVAr) reserves are severely depleted.

Nominal Voltage	Base Case and Contingency Limits (kV)
400kV	360 - 420
275kV	248 - 307
220kV	198 - 246
110kV	99 - 123

Table 2 - SOGL Voltage Limits

3.3.4. Power Flows

The fundamental objective of a transmission system is to transport electricity from the generation source to the demand centres. All plant and equipment that carries electricity have a thermal limit beyond which it will fail to operate safely; therefore it is the responsibility of the TSO to ensure the transmission system is operated within the thermal limits. However, during system disturbances, such as immediately post-fault, a temporary overload rating may apply where the rating may exceed 100% of the normal (pre-fault) rating. Depending on the type of plant this temporary rating may apply for a maximum of a few minutes to a couple of hours and allows the TSO time to recover the system to within normal ratings.

3.3.5. System Instability

Instability of a power system could cover numerous scenarios including voltage and frequency issues mentioned above. However, with the changing nature of generation towards more renewable sources the system inertia (a measure of how robust the system is to disturbances) is reducing and has to be monitored closely. There has been detailed offline analysis carried out to provide certain constraints to manage inertia, e.g.

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there is a percentage limit on the System Non-Synchronous (generation) Penetration (SNSP) figure and there are a certain number of synchronous machine units constrained to run to ensure the system inertia remains above a minimum level. These constraints and others are published monthly in the Operational Constraints Update[14] and are used in the online transient stability assessment tool.

3.4. Operation of a Power System by EirGrid

As discussed in the Balancing Market Principles Statement (BMPS), the main objectives of EirGrid, as TSO, in operating the power system are to:

1. Ensure operational security
2. Maximise renewable sources
3. Provide efficient operation of the market

The requirement to provide transparency is an overarching obligation and EirGrid supports the transparency objective through the design of our processes and tools including a range of publications, such as the BMPS which describes the Scheduling and Dispatch process summarised below in greater detail.

Starting in the longer term (in outage planning timescales), offline analysis is carried out to calculate the operating reserve requirements and system constraints which are published monthly in the Operational Constraints Update. Still in outage planning timescales but nearer real-time there is a Weekly Operational Constraints Update published based on offline studies with the forecast system outages. This is to provide information on any forecasted significant network congestion or other issues that could potentially restrict dispatchable generation in a particular area or to flag if dispatchable generation is required in a particular area.

All these constraints are fed into EirGrid's scheduling tool which is looking up to 30 hours ahead of real-time using the currently connected generation technical data and wind forecasts. This produces a secured schedule for each half-hour for the following day that meets the demand forecast and satisfies the constraints (incl. reserve) delivered in the most efficient and economical way.

This secured schedule is refined approximately every 4 hours on the actual day. Then at 4 hours ahead there is the RTC schedule (Real Time Commitment on units to be dispatched) refined every 15 minutes followed at one hour ahead by the RTD schedule (Real Time Dispatch showing indicative units to increase or decrease) refined every 5 minutes.

[14] http://www.eirgridgroup.com/library/index.xml, filter on Operations then Constraints Update.

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While the above schedules are created using the indicative demand and generation patterns, the TSO uses the EMS (Energy Management System) to provide real-time indication and control of the power system, which includes a SCADA (Supervisory Control and Data Acquisition) system for gathering real-time data from the power system. This runs a full contingency analysis every minute to flag up any predicted violations of voltage or thermal limits.

Also in real-time, the WSAT (Wind Stability Assessment Tool) runs every 5 minutes testing the transient stability of the system on all defined contingencies. The output is a prediction of the frequency nadir and the likely rate of change of frequency for each credible event. Real-time information is provided to the operators as alarms when any limit is approached so that manual actions may be taken as necessary.

3.4.1. Frequency Management

The system frequency is monitored on a second by second basis by the TSO. Through a combination of frequency regulation from various responsive plant and dispatch of generating units to change their output level, frequency is maintained within the Standard Frequency range (see Table 1) under normal system conditions.

Frequency regulation is managed through the provision of different types of reserve products described in SOGL. The SAOA maps the existing Grid Code reserve products (Primary, Secondary and Tertiary Operating Reserve – POR, SOR, TOR) to the SOGL categories, see below. For all reserve providers, the reserve capability is mandated by the Grid Code and contracted via System Services agreements. These measures to control frequency are available for the TSO to select the most economic service providers.

While there are commercial services available to the TSO, such as Fast Frequency Response, this discussion is concentrating on the SOGL defined reserve services. Therefore, the initial response to managing the frequency is provided by Frequency Containment Reserves (FCR) (previously POR & SOR) which acts within 90 seconds.

Frequency Restoration Reserves (FRR) (previously TOR) is fully available after 90 seconds and is sustainable for up to 20 minutes.

Sufficient FCR and FRR are held to ensure that for the loss of the largest single power infeed to / or outfeed from the system at any time, the system frequency (See also Figure 3 – System States during a Frequency Transient):

- deviation does not exceed the Maximum Instantaneous Frequency Deviation of 1000 mHz and returns to within the Maximum Steady State Frequency Deviation within 1 minute

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- deviation does not exceed the Maximum Steady State Frequency Deviation (+/- 500 mHz) after 1 minute and returns to the Standard Frequency Range within 15 minutes

- deviation remains within the Standard Frequency range (50 +/- 200 mHz) after 15 minutes with a quality target outside this range limited to a maximum 15,000 minutes annually for all conditions

To ensure there are sufficient frequency response services ahead of real-time, these requirements are included in the scheduling tools calculating each half-hour scheduling period from 30 hours ahead based on the largest infeed loss for that interval. Together with other variables such as demand characteristics, technical and commercial data a co-optimisation of system services is scheduled to ensure reserve requirements are always met economically and efficiently.

Following any frequency incident where reserves have been depleted, such as an unexpected loss of a large generator, Replacement Reserve (RR) will be dispatched to recover the operating reserve within 20 minutes and is sustainable for up to 4 hours to cover for the next contingency.

The East West Interconnector (EWIC) link to Great Britain can provide a low and high frequency response service to both power systems. For low frequency events in Ireland EWIC can provide response using its Frequency Control – Sensitive Mode (FC-SM). Once system frequency reaches 49.80Hz, EWIC will start providing response at a rate of 500MW/Hz up to the maximum agreed MW value at a frequency of 49.65Hz. The maximum MW value is currently 75MW. The response will be maintained below the lower frequency value and once the frequency rises above 49.65Hz the response will begin decreasing (at 500MW/Hz) until reaching 49.80Hz when the response will have reduced to zero. Depending on the frequency deviation and the duration of the response, it is classed as FCR or FRR.

For a high frequency in Ireland, once system frequency reaches 50.20Hz, EWIC will start providing response with at a rate of 500MW/Hz up to the maximum agreed MW value at a frequency of 50.35Hz. The maximum MW value is currently 75MW. The response will be maintained above the higher frequency value and once the frequency falls below 50.35Hz the response will begin decreasing (at 500MW/Hz) until reaching 50.20Hz when the response will have reduced to zero. Depending on the frequency deviation and the duration of the response, it is classed as FCR or FRR.

In accordance with SOGL and applied in the Grid Code all Interconnectors must remain connected to the transmission system and operational between 47.0 Hz up to 52.0Hz (below 47.5Hz they only need to stay operational for 30 seconds).

Should the frequency fall unexpectedly outside the Maximum Steady State Frequency Deviation limits then automatic under/over frequency control schemes and/or Low Frequency Demand Disconnection schemes operate, see sections 5.1 and 5.2.

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3.4.2. Voltage Management

The correct control of the system voltage is fundamental to the safe and secure operation of the power system. The TSO is obliged to operate the transmission system with the operational security limits defined in SOGL, see Table 2.

However, EirGrid has a more stringent set of voltage limits in operational timescales, the Normal System Voltage range:

Nominal Voltage	Base Case Limits (kV)	Post Contingency Limits (kV)
400kV	395 - 410	360 - 420
275kV	275 - 285	250 - 303
220kV	225 - 238	200 - 242
110kV	110 - 118	99 - 121

Table 3 - Irelands Voltage Limits

Managing the system to a tighter range around the nominal voltage helps to ensure the long-term system security and integrity of plant.

Assessments are carried out in Long Term Planning timescales to identify certain “must run” generation units due to voltage constraints in localised areas. This analysis is carried out on an offline study. In real time there is an online contingency analysis testing each contingency in turn which is updated using latest wind forecasts and real time data, in order to take pre-emptive action to avoid a post fault breach of the voltage limits. This real time analysis takes place continuously.

The voltage management of the system is achieved in a number of ways and the options available to engineers in operational timescales are:

- switching reactive compensation equipment
    - Capacitors
    - Reactors
- Instructing MVAr on synchronous generation
- Changing target voltage set points
    - Static Variable Compensators (SVCs)
    - Power Park Modules (PPM)
- Switching out high reactive gain circuits
- Simultaneous tap changing of NCC controlled grid transformers
- Tap staggering of parallel NCC controlled system transformers

These measures are all designed to ensure the system remains within the Normal System voltage range with sufficient voltage support (MVAr) reserves to limit the voltage step change post contingency within the post-contingency limits and hence avoid an Emergency state. Specifically for voltage issues, an Emergency state is when at least

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one violation of voltage limits is active and or widespread (multiple) under voltage load shedding activated.

3.4.3. Power Flow Management

Power flows across the synchronous area of Ireland are managed by the TSOs. In accordance with the Balancing Market Principles Statement, system constraints are one of the inputs into the optimisation tools so that transmission plant outages are taken into account. The objective is to ensure that the system is operated within the thermal limits of the transmission equipment.

Standard remedial actions to maintain the system in Normal State include:

- Re-switching circuits to restrict flows
- Return of outage plant to remove system overload
- Re-dispatch active power set points for generators online
- Schedule additional generation
- Tap change of transformers
- Adjust active power flows through HVDC systems with other TSOs

Under fault conditions temporary (emergency) load conditions may be applied to equipment as system conditions dictate. If a severe overload is anticipated for a post-fault condition automatic protection schemes may be used to preserve the integrity of the transmission plant and apparatus.

These measures are all designed to ensure the system remains within the standard pre and post contingency operating capability and hence avoid entering an Emergency state. Specifically as regards thermal issues, an Emergency state is when at least one violation of current limits on transmission plant is active, or activation of system separation protection.

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4. Design of the System Defence Plan

4.1. Objectives of the SDP

The SDP is designed to conform to the NCER Articles 11 to 22 and it is intended to serve as an oversight document referencing the more detailed plans. Should the detailed plans change to take into account the characteristics of the transmission system or underlying DSO systems, due to the behaviour and capabilities of load and generation within the synchronous area, then changes would be made in accordance with the NCER.

As referenced in NCER Article 11(5), the SDP contains the following technical and organisational measures:

System protection schemes (automatically initiated) including:

- automatic under-frequency control scheme
- automatic over-frequency control scheme
- automatic scheme against voltage collapse

System defence plan procedures (manually instructed) including:

- frequency deviation management procedure
- voltage deviation management procedure
- power flow management procedure
- assistance for active power procedure
- manual demand disconnection procedure

Some of the above measures may be provided by neighbouring TSOs and while TSO assistance is not in the group of measures listed in the NCER Article 11(5), Inter-TSO assistance and co-ordination in an Emergency state is prescribed in NCER Article 14 to ensure consistency of co-operation across the EU TSOs.

In developing the SDP measures, which may be provided by designated SGUs, EirGrid has co-ordinated and consulted with the DSO on the production of this document to ensure the following NCER principles are met:

- the impact of the measures on the system users shall be minimal
- the measures shall be economically efficient
- only those measures that are necessary shall be activated
- the measures shall not lead the TSO's transmission system or the interconnected transmission systems into Emergency state or Blackout state.

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NCER Article 11(3) lists the following provisions that the SDP must contain:

a) *The conditions under which the SDP is activated;*
b) *The SDP instructions to be issued by the TSO; and*
c) *The measure subject to real-time consultation or coordination with the identified parties.*

For a) please see next section for a detailed explanation, whereas b) and c) may be described more generally. The system defence measures discussed in this section and described in greater detail in section 5 are all existing measures currently available to the TSO, and there are well established communication channels and relevant procedures. This is the case for all SGUs and the DSO.

All automatic control schemes are activated when the relevant threshold is reached and instructions or real-time consultation is not possible, whereas for the manual procedures a significant majority of the procedures is the TSO directing the defence service providers, usually via dispatch instructions, or the DSO via control room telephony. Where a manual procedure is initiated by instruction from the TSO this is highlighted in the section description of the measure.

4.2. Activating the SDP

The SDP contains (manual) procedures and automatic schemes available to the TSO to prevent the further deterioration towards an Emergency state when one is forecast or to manage the system when it is in an Emergency state.

The NCER states, as per below, that system defence measures can be activated once the system is in Emergency state or, alongside remedial actions based on operational security analysis, to prevent the system from entering the Emergency state.

NCER Article 13 (2) states, *in addition to the automatically activated schemes of the system defence plan, pursuant to point (a) of Article 11(5), each TSO shall activate a procedure of the system defence plan when:*

> *(a) the system is in emergency state in accordance with the criteria set out in Article 18(3) of Regulation (EU) 2017/1485 and there are no remedial actions available to restore the system to the normal state; or*
>
> *(b) based on the operational security analysis, the operational security of the transmission system requires the activation of a measure of the system defence plan pursuant to Article 11(5) in addition to the available remedial actions.*

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Each TSO uses ‘remedial actions’ to prevent their system from deteriorating and transitioning away from the Normal system state. These actions are categorised in SOGL (Article 22 refers) in general terms and some have been described in section 3.4 above. NCER re-classifies these actions as system defence measures when these actions are included in the system defence plan.

As noted in the previous section NCER divides system defence measures into automatic schemes and manual procedures, therefore automatic schemes in the SDP may be described as:

- those initiated when the trigger threshold for each particular scheme is reached, e.g. low frequency relay, and when system is in Emergency state.

Manual procedures in the SDP may be described as:

- those that are instructed when the system is in Emergency state when there are no remedial actions available (NCER 13 (2) (a)), or
- those that are instructed based on a forecast that the system will enter an Emergency state even with available remedial actions being activated (NCER 13 (2) (b))

Consideration is given below to the differences between remedial actions and manual procedures in the SDP.

The TSO has various actions available to correct various phenomena (frequency or voltage or power flows outside relevant operational limits) whereby some remedial actions and system defence procedures may require similar actions. It is important to note that the differentiation can be attributed to the status of the system when the measure is applied.

Remedial actions are applied first within Normal/Alert state and if these remedial actions are no longer effective in either;

- a timed capacity (not fast acting enough to stop the system entering Emergency state), or
- a resource capacity (not adequate to stop the system entering Emergency state), then

the SDP is activated and the resulting actions are system defence procedures.

In summary a system defence measure may be described as either:

- An automatic or manual corrective action initiated / instructed during an Emergency state, or
- A manual corrective action, designed to be used during an Emergency state, instructed when an Emergency state is forecast.

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A mapping table has been provided in Table 4 below to show which actions are part of the SDP and which are categorised as remedial actions. Note that some actions may be initiated manually during the Normal and Alert state and may be thought as a remedial action; however, they are a system defence procedure if the system is expected to transition into the Emergency state. This is typical of the transient nature of events impacting on the transmission system.

Table 4 contains the automatic scheme or manual procedure discussed above in chronological order of NCER Articles and colour coded on the left hand side of the table. By identifying all the actions available to the TSO in each category it is categorised against a remedial action or system defence measure as defined above. Again it is colour-coded for ease, with red filled boxes , x, denoting a system defence measure; a blue filled boxes x denoting a remedial action and green filled boxes, x denoting an action that could be a remedial action or a system defence measure depending when the action was initiated. All the actions identified as system defence measure are discussed in detail in chapter 5.

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Table 4 – Mapping Table - Remedial Actions Vs System Defence Measures

	Article	NCER Chapter II Section 2 Technical & Organisational Measures	Control Scheme / Management Procedure	Remedial Action	System Defence Measure	Reasoning
System Protection Schemes	15	Automatic Under Frequency Control Schemes	LFDD		X	Low Frequency Relays triggered from 48.85Hz
			Energy Storage Providers		(X)	Currently none available, however, proposed frequency threshold is 49.0Hz
	16	Automatic Over-Frequency Control Schemes	OFGS		X	High Frequency Relay triggered from 50.50Hz
			Step wise linear disconnection		X	Triggered from Frequency Threshold of 50.5Hz
	17	Automatic Scheme Against Voltage Collapse	UVLS (Low voltage Demand disconnection)		X	Scheme triggered when local voltage is below voltage standards
			Automatic Blocking Auto-tap transformers scheme			Confirmed that automatic scheme is not required.
System Defence Plan Procedures	18	Frequency Deviation Management Procedure	Standard Frequency Management Actions	X		Remedial Actions as taken in Normal / Alert state
			Operating Reserve - FCR	X		Remedial Action as FCR is as initiated within 15 seconds of frequency deviation
			Operating Reserve - FRR	X	X	FRR may be Remedial Action or System Defence Measure depending on system state when initiated (15s - 90s)
			Operating Reserve - RR	X	X	RR may be Remedial Action or System Defence Measure depending on system state when initiated (20mins)
			Limited Frequency Sensitive Mode - Under	X		LFSM-U is designed to be initiated at 49.5Hz, however, policy for it to start at 49.8Hz to be consistent with Non-RfG PPMs. Therefore a Remedial Action.
			Limited Frequency Sensitive Mode - Over	X		LFSM -O is Remedial Action as initiated at 50.20Hz
			East West Interconnector	X		Frequency Control - Sensitive Mode is a Remedial Action as initiated at 49.80Hz (Low) or 50.20Hz (High).
			Turlough Hill pump storage	X	X	For Low Freq. Remedial Action if initiated in turbine mode & System Defence Measure if initiated in pump mode. For High Freq. System Defence Measure as trips at 51.50Hz
			Active power set points within technical parameters when Frequency is outside Alert Limits.		X	Generators and DSUs dispatched centrally even if Frequency is outside Alert Limits. Therefore a System Defence Measure.
			Authority to disconnect SGUs		X	Low Freq.: System Defence Measure as possible if below 49.50Hz and above 48.85Hz (LFDD threshold), see manual demand disconnection. High Freq.: Rare to be a System Defence Measure as above
			Energy Storage Providers		(X)	ESS: Before LFDD triggered: change load to Gen mode or trip load? Currently none available.
	19	Voltage Deviation Management Procedure	Standard Voltage Management Actions	X		Remedial Actions as taken in Normal / Alert state
			Authority to establish reactive power set-points & running additional generation for MVars		X	Generators and DSUs dispatched centrally even if outside operational security Limits. Therefore a System Defence Measure.
			Other TSO making MVars available		X	System Defence Measure as requesting Emergency Assistance for reactive power from TSOs not in Emergency state.
	20	Power Flow Management Procedure	Standard Power Flow Management Actions	X		Remedial Actions as taken in Normal / Alert state
			Active power set points within technical parameters (Special Actions)		X	Generators and DSUs dispatched centrally even if outside operational security Limits. Therefore a System Defence Measure.
			Authority to disconnect SGUs inc. Special Protection Schemes (Thermal)		X	Disconnection of circuits to prevent excessive thermal overload outside operational limits. Therefore System Defence Measure.
	21	Assistance for Active Power Procedure	Balancing service provider		X	Generators and DSUs dispatched centrally even if system adequacy is lacking. Therefore a System Defence Measure.
			Non-Balancing service provider (non- available)		(X)	Currently none available.
			East West Interconnector		X	System Defence Measure as requesting Emergency Assistance for active power from TSOs not in Emergency state.
	22	Manual Demand Disconnection Procedure	Emergency load shedding (5min)		X	Manual Action to avoid prolonging Emergency state (frequency deterioration, thermal overloads, and under voltage). Therefore a System Defence Measure.
			Emergency load shedding (30mins)		X	Manual Action to avoid prolonging Emergency state (frequency deterioration, thermal overloads, and under voltage). Therefore a System Defence Measure.
			Rota Load shedding		X	Manual Action to avoid prolonging Emergency state (frequency deterioration, thermal overloads, and under voltage). Therefore a System Defence Measure.

4.3. Application of the SDP

As outlined in NCER Article 2, SGUs for this regulation include the following:

- Generators from 5MW upwards (Type C , D)
- Generators from 100kW to < 5MW (Type B) where these units are identified as SGUs
- transmission-connected demand facilities
- transmission connected closed distribution systems
- aggregators of re-dispatching of power generating modules or demand facilities and providers of active power reserve
- HVDC Interconnector Owners

For clarity, the tabular format and graph of the RfG generator types are presented in Table 5 – Limits for thresholds for type B, C and D power-generating modulesbelow.

Synchronous areas	Limit for maximum capacity threshold from which a power-generating module is of type B	Limit for maximum capacity threshold from which a power-generating module is of type C	Limit for maximum capacity threshold from which a power-generating module is of type D
Continental Europe	1 MW	50 MW	75 MW
Great Britain	1 MW	50 MW	75 MW
Nordic	1,5 MW	10 MW	30 MW
Ireland and Northern Ireland	0,1 MW	5 MW	10 MW
Baltic	0,5 MW	10 MW	15 MW

Table 5 – Limits for thresholds for type B, C and D power-generating modules

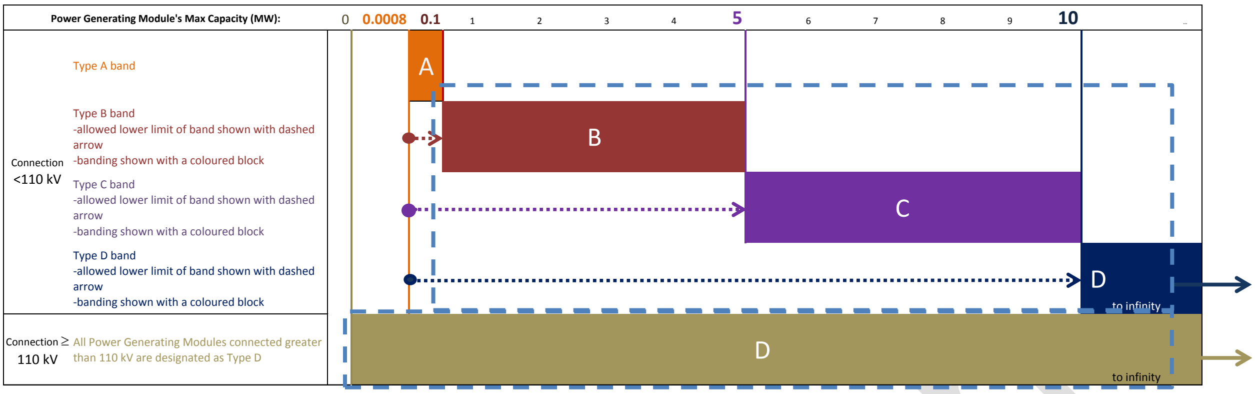

Figure 4 - Limits for thresholds for type B, C and D power-generating modules

By mapping the individual system defence services, see later in Chapter 5, against the SGUs, Table 6 below is produced to demonstrate the system service providers. Note some services are meeting more than one system defence measure, e.g. instructing Active Power set points.

All these services are existing actions available to the TSO and may be cross-referenced against the existing obligations in the Grid Code. When comparing the Grid Code defined 'Demand Side Units' and 'Centrally Dispatched Generating Units' these may be viewed as 'transmission-connected demand facilities / aggregators of demand facilities' and generally Type C & D Generators, respectively.

As can be seen from the table, the following SGU, 'Transmission connected closed distribution systems' has not been mapped to a service as we do not currently have this category of SGU on the system.

To show the link from Table 4, Table 6 is in chronological order of NCER Articles, however, this time it shows only the system defence measure mapped against providers, i.e. the white cells from Table 4 have not been carried forward. As noted at the beginning of this section the DSO and their distribution connected demand customers are not SGUs in accordance with NCER. Whereas distribution connected generators Type D & C (all cases) and B (where they are so defined) are SGUs.

There are system defence measures discussed in chapter 5 which directly impact distribution connected demand customers, such as Manual Demand Disconnection, however, they are not classified as a defence service provider as they are not SGUs.

Where the service provider is solely the distributed demand customer this has been highlighted in a red filled box and mapped against a Non-SGU. The mapping for the remaining defence measures against SGUs has been highlighted in yellow filled boxes.

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			SGUs								Non-SGUs
NCER Article	NCER Chapter II Section 2 Technical & Organisational Measures	Individual System Defence Measure / Service	Type D Generator (T-Connected)	Type D Generator (D-Connected)	Type C Generator	Type B Generator	Aggregators of Gen/ Dem	T -Conn Demand Facility	Interconnector Owners	T-Conn closed Distribution System	DSO Demand Customers
15	Automatic Under Frequency Control Schemes	LFDD (Low Frequency Demand Disconnection									X*
16	Automatic Over-Frequency Control Schemes	Over Frequency Generator Shedding Scheme	X								
		Step wise linear disconnection	X	X	X	X					
17	Automatic Scheme Against Voltage Collapse	UVLS (Low voltage Demand disconnection)									X**
18	Frequency Deviation Management Procedure	Operational Reserve (FRR) (Inc. Turlough Hill)	X	X	X	X	X				
		Replacement Reserve (RR)	X	X	X	X	X				
		Active power set points when Frequency is outside Alert Limits.	X	X	X	X	X				
		Authority to disconnect SGUs	X	X	X	X	X	X	X		
19	Voltage Deviation Management Procedure	Reactive power set-points	X								
		Other TSO's making Mvars available							X		
20	Power Flow Management Procedure	Active power set points when power flow is outside Alert Limits.	X	X	X	X	X				
		Special Protection Schemes	X	X	X	X					
21	Assistance for Active Power Procedure	Active power set points when system adequacy is lacking.	X	X	X	X	X				
		Interconnectors Emergency Assistance (MWs)							X		
22	Manual Demand Disconnection Procedure	Emergency load shedding (inc. 5m , 10m & Rota)									X*

* Unless Exempted
** At locations designated by the TSO

Table 6 - Mapping of SD Services against SGUs/ Non- SGUs

To simplify the mapping table, Table 7 has been provided to show the remaining system defence measures provided by SGUs in order of the service provided by most SGUs. Please note that some similar services from the same providers have been merged to minimise this summary table. Table 7 will be taken forward in the complementary document where Terms and Conditions for providing these services is discussed.

	SGUs							
Individual System Defence Measure / Service	**Type D Generator (T-Connected)**	**Type D Generator (D-Connected)**	**Type C Generator**	**Type B Generator**	**Aggregators of Gen/ Dem**	**T -Conn Demand Facility**	**Interconnector Owners**	**T-Conn closed Distribution Systems**
Authority to disconnect SGUs	X	X	X	X	X	X	X	
Operational Reserve (FRR) (Inc. Turlough Hill)	X	X	X	X	X			
Replacement Reserve (RR)	X	X	X	X	X			
Active power set points when Freq./ Power Flow is outside Alert limits and system adequacy is lacking	X	X	X	X	X			
Special Protection Schemes (Inc. Step wise linear diaconnection)	X	X	X	X				
Over Frequency Generator Shedding Scheme	X							
Reactive power set-points	X							
Interconnector Emergency Assistance (MWs) & Making Mvars available							X	

Table 7 - Simplified Mapping of System Defence services against SGUs

4.3.1. High Priority SGUs

In accordance with NCER, the TSO is to submit to the CRU for approval the list of High Priority SGUs, which is defined as '*the SGU for which special conditions apply for disconnection and re-energisation*'.

In the Grid Code Priority Customers is a defined term which refers to customer that are excluded from Demand Control, GC OC.5.1.5 refers. Similarly, in the D-Code Demand Control is exercised equitable between customers, however, exemptions may apply to vital and priority customers as defined in the distribution load shedding plan, DOC5.1.4, refers.

There are two categories of exempt customers:

1. the first are customers who are not shed because of the risk to life or national security, i.e. hospitals, prisons, airports etc..., and
2. the second are the larger industrial customers where there is risk of severe consequential loss to production or plant, or where the standard rota shedding system could have severe consequences for employment and the economy.

Some aspects of this criterion and processes for selection of Exempt Customers are the subject of on-going review by ESBN and may be subject to change following engagements with CRU and potential further public consultations. In all of these situations it will have to be made clear to customers that "priority" service is ultimately determined by available resources and cannot be guaranteed.

While there is a category for exempt customers connected to the distribution system there are currently no identified equivalent customers connected to the transmission system. As mentioned above, distribution connected demand customers exempt or otherwise are not classified as SGUs under NCER, hence there are no identified High Priority SGUs identified for this SDP.

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5. System Defence Plan - Measures

The SDP requires specific 'measures' to be in place as part of the implementation of the SDP. These measures include automatic schemes and procedures. The automatic schemes are identified as system defence measures if they are initiated when in the system is in Emergency state, whereas the procedures are all designed to be implemented when the system is in, or forecast to be imminently in an Emergency state.

The automatic schemes include;

- Automatic under-frequency control schemes
- Automatic over-frequency control schemes
- Automatic scheme against voltage collapse

The procedures include;

- Frequency deviation management procedure
- Voltage deviation management procedure
- Power flow management procedure
- Assistance for active power procedure
- Manual demand disconnection procedure

These schemes and procedures are discussed in turn in this chapter.

5.1. Automatic under-frequency control scheme

[In accordance with NCER Article 15]

5.1.1. Automatic Low Frequency Demand Disconnection

A low frequency demand disconnection scheme is in place on the power system. This scheme is designed and implemented in collaboration between TSO and the DSO to ensure sufficient demand can be disconnected in the event of an exceptional low frequency event on the power system in Ireland.

This scheme is designed to disconnect tranches of system demand at falling frequency thresholds. Under-frequency load shedding relays are installed at designated substations around Ireland with the capability of disconnecting up to 60% of system demand, triggered at an initial frequency of 48.85 Hz, which is within the Emergency state. This scheme aims to disconnect load to stabilise system frequency, and the lowest

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frequency threshold at which load is disconnected is 48.50 Hz. The DSO provides the geographical dispersion of the affected load across Ireland.

The current settings applied to the installed under frequency relays are detailed in the Table 6 below. The process is for the TSO to confirm to the DSO the number, size and the associated low frequency settings of these blocks, as specified in Grid Code OC5.5. The requirement is mandated on the TSO and DSO therefore no service agreements are involved. Note the settings are in accordance with the requirements of the NCER Article 15(5) and the scheme characteristics listed in the Annex for synchronous area of Ireland, reproduced as Figure 5 below for clarity. The settings are reviewed from time to time and any amendments will be in accordance with NCER.

Frequency (Hz)	(%) of total RoI area Demand
48.85	10
48.80	10
48.75	4
48.70	4
48.65	4
48.60	4
48.55	12
48.50	12

Table 8 – Percentage Demand Disconnection Set points

Automatic low frequency demand disconnection scheme characteristics:

Parameter	Values SA Continental Europe	Values SA Nordic	Values SA Great Britain	Values SA Ireland	Measuring Unit
Demand disconnection starting mandatory level: Frequency	49	48,7 – 48,8	48,8	48,85	Hz
Demand disconnection starting mandatory level: Demand to be disconnected	5	5	5	6	% of the Total Load at national level
Demand disconnection final mandatory level: Frequency	48	48	48	48,5	Hz
Demand disconnection final mandatory level: Cumulative Demand to be disconnected	45	30	50	60	% of the Total Load at national level
Implementation range	± 7	± 10	± 10	± 7	% of the Total Load at national level, for a given Frequency
Minimum number of steps to reach the final mandatory level	6	2	4	6	Number of steps
Maximum Demand disconnection for each step	10	15	10	12	% of the Total Load at national level, for a given step

Figure 5 – Automatic low frequency demand disconnection scheme characteristics

Following the activation of this scheme, Automatic Frequency Restoration (AFR) provides for the orderly restoration of all shed load in periods ranging from 0 to 6 minutes in 6 seconds steps once system frequency has returned to 49.90Hz, Grid Code OC.5.6 refers.

5.1.2. Management of Energy Storage Devices

There are multiple Battery Energy Storage Units progressing connections to the transmission and distribution systems, one which has recently reached the energisation stage and others with delivery dates into 2020 and beyond. As noted in NCER, we believe these energy storage devices will become important providers of under-frequency service in the future.

As this is new technology, we are working with providers to assess their capabilities and system services, e.g. recent volume capped tenders[15]. We will continue to work with providers to agree reserve trigger frequencies and trajectories, noting that until the technology can meet NCER Article 15(3)(a) where the energy storage load can automatically switch to generation mode; we will ensure the energy storage device can automatically disconnect itself in accordance with NCER Article 15(3)(b) and in the frequency range between 48.85Hz and 49.00Hz in accordance with NCER Article 15(4).

Grid Code Connection Conditions 7.3.1.4 & 7.3.1.5 provides for the Generators of new technology to perform at maximum flexibility to their units operating characteristics in accordance with Good industry Practice. Also, the TSO and the Generator are to cooperate and develop procedures to improve response of each generating unit during conditions of system stress.

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15 http://www.eirgridgroup.com/how-the-grid-works/ds3-programme/ds3-consultations-and-pub/

5.2. Automatic Over-frequency control scheme

[In accordance with NCER Article 16]

5.2.1. Over Frequency Generation Shedding (OFGS) Scheme

To help manage the frequency when facilitating the full export on EWIC various tranches of wind farms are selected to trip for increasingly higher frequency, see Table 9.

In this scenario EWIC will be the largest loss on the system and this is currently only likely when wind farms in Ireland are near full capability; therefore, only wind farms are selected in this scheme. Note this scheme is from 50.50Hz to 50.75Hz and is an action within the Emergency state if the frequency deviation remains above 50.5Hz for more than one minute.

Trigger (Hz)	Tranche – Geographical Area	Approx.Maximum Export Capability (MW)
50.50	1. South West	100
50.55	2. North West & East	130
50.60	3. South West & South East	150
50.65	4. North West & West	160
50.70	5. South West & South East & Mids	160
50.75	6. South West and West	190

Table 9 – Over Frequency Generation Shedding Set Points

This scheme is implemented by the TSO on the protection relays at designated transmission substations. This is not contracted under a system service agreement but mandated under the Grid Code, OC6.7.4.1 (f) refers, which is a general clause for the TSO to de-energise User's (including DSO connected) for safe & secure operation of the transmission system and clause (f) specifically mentions when operating outside the normal frequency range.

5.2.2. Step Wise Linear Disconnection

NCER Article 16 (3) specifically mentions if the automatic over-frequency control scheme is insufficient to manage against the largest export then the TSO shall set up an additional step-wise linear disconnection scheme. As noted above, the OFGS is designed to manage the largest export of 500MW so there is no TSO instructed scheme in place.

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However, we are aware that various generators have over-frequency relays set to trip their generators at incremental frequencies from 50.50 Hz to 52.00Hz (the minimum withstand capability set by SOGL) and beyond, e.g. Turlough Hill has over-frequency relays set at 51.5Hz to trip all four units after 12 seconds if in turbine mode.

The Grid Code CC.10.9.2 (b) and CC.10.10.2(f) provide the TSO the mandate to specify these over frequency protection schemes on both transmission and distribution connected generating units in the future if required.

5.3. Automatic Scheme against Voltage Collapse

[In accordance with NCER Article 17]

There is one main automatic scheme installed to prevent voltage collapse, a scheme for low voltage demand disconnection known as Automatic Under Voltage Load Shedding (UVLS).

As noted in NCER Article 17 the automatic scheme against voltage collapse of the system defence plan may include a blocking scheme for on load tap changers, however, this requirement is dependent on a TSO assessment of need. No such need has been identified and we can confirm that no such agreement is in place with the DSO at the time of writing.

5.3.1. Automatic under-voltage load shedding (UVLS)

The purpose of the UVLS is to prevent a local voltage collapse cascading into a wider voltage collapse or system blackout. UVLS relays act alone or in small groups of two or three. UVLS is not implemented across the whole system but in local areas in lieu of network re-enforcement. There are a total of eight 110kV stations with a UVLS scheme equally distributed across the system. These are reviewed regularly to ensure demand is not unnecessarily at risk.

The majority of the UVLS relays will operate if the 110kV voltage is detected at 95kV or below. There is a short time delay of between 5 to 15 seconds before the circuit breakers open and shed 30-35% of load. This automatic defence measure is mandated within the Grid Code OC.5.7, where on request from the TSO, the DSO will co-operate with the design and location of automatic low voltage demand disconnection. Any settings are specified by TSO in discussion with the DSO to ensure the exempt customers are not included.

Load shedding may also be instructed manually as an emergency action, please see section 5.8 discussing Manual Demand Disconnection as it is employed not only for voltage issues but for frequency and thermal overload issues on transmission plant.

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5.4. Frequency Deviation Management Procedure

[In accordance with NCER Article 18]

In accordance with NCER the Frequency Deviation Management procedures for the SDP are to be used when the frequency is outside Normal and Alert state limits or forecast to do so without any further corrective actions.

As mentioned within section 3.4.1 Frequency Management, generation regulating reserve is the first line of defence against a frequency deviation and while some procedures initiate before the system is in an Emergency state, and are hence categorised as remedial actions (as recognised in NCER Article 18(1)); the provision of operating reserve initiated after the 'time to recover frequency' has elapsed and hence during an Emergency state may be categorised as a system defence measure.

The general order in which sources of under frequency measures are applied is:

1. Generating units provide frequency response
    a. Synchronous generating units govern upwards (FSM)
    b. Non-synchronous (windfarm) units provide full available active power (LFSM-U)
2. Interconnector response
3. Demand side unit response
4. Pump storage response
5. Load shedding

In a similar way to managing low frequency deviations, high frequency deviations follows a similar pattern.

The general order in which sources of over frequency measures are applied is:

1. Generating units provide frequency response
    a. Synchronous generating units govern downwards (FSM)
    b. Non-synchronous (windfarm) units reduce output to Minimum Load (LFSM-O)
2. Interconnector response
3. Over Frequency Generator Shedding scheme
4. Generators are tripped

Please note, in accordance with NCER Article 15(2) all generation is either in FSM or LFSM (Grid Code CC.7.3.1; CC.7.3.1.1 (u) refers). Please note that while LFSM-U is designed to initiate a response at a frequency threshold of 49.50Hz (Grid Code OC.4.3.4.1.9 & PPM1.5.3.12 refers) all generating unit PPMs will follow the curve for wind following (Non-RfG) Generating Units that initiate a response at a frequency of 49.80Hz. This is to ensure all non-RfG and RfG generating Units PPMs throughout the system are controlled identically while ensuring compliance with the RfG. LFSM-O

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initiates a response at a frequency threshold of 50.20Hz and therefore the system is not in an Emergency state for either LFSM modes and are not categorised as a system defence measure (Grid Code PPM1.5.3.11, refers).

Those frequency defence measures that are initiated during an emergency state are listed separately in the sections below.

In accordance with SOGL, RfG and DCC (and applied through Grid Code), all generation (and Demand side Units) must remain synchronised and providing reserve from 52.00Hz down to 47.00Hz, albeit below 47.50Hz they only need to stay operational for 20 seconds.

5.4.1. Demand Side Response

Several Demand Side Units currently provide under frequency response and not all achieve this by disconnecting load. While disconnection of load is the largest proportion of demand side response, other sites achieve their response through a combination of fast wind down of processes, dynamic load reduction or displacement of net import from the grid using secondary energy sources such as batteries or fast starting generation.

The response characteristics vary unit by unit; however, FRR will be a system defence measure if a significant deviation remains below 49.50Hz for a minimum of one minute and hence the system is in an Emergency state. Additionally, demand side units providing static response will have thresholds of between 49.80Hz and 49.30Hz and may also be categorised as a defence measure, depending on the system state active at the time of initiation.

5.4.2. Turlough Hill Pump Storage

Turlough Hill is a pump storage station, consisting of an upper and lower reservoir and four units, each with a registered capacity of 73 MW. All four units share a common penstock from the upper reservoir to the turbines, therefore units cannot pump and generate simultaneously. The units have a number of different modes of operation and these are described below.

The five modes of operation for each of the four units are as follows:

1. Standstill Mode (offline)
2. Turbine Mode (generating)
3. Pump Mode (load)
4. Spin Gen Mode (spinning in air in the turbine direction)
5. Spin Pump Mode (spinning in air in the pump direction)

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The units are all fitted with under frequency relays. In the event that the frequency falls below a set level then the units, depending on their mode of operation, will change to either a new mode or maximum generation.

The relay settings can be rotated between all units and any changes to these settings are agreed with the TSO. Note that pumps will be tripped according to the under frequency settings. Once all but one of the pumps has tripped, the last remaining pump will proceed to Turbine mode if the frequency stays below the setting. There is a Programmable Logic Controller (PLC) which determines under-frequency settings applied to the pumps each time a pump enters or leaves operation.

The under frequency relays are set at various steps, starting from 49.8Hz (lower limit of standard frequency range) to 49.2Hz. This provides the capability for all four units to be generating at full load at the lowest frequency setting, even if all four units were in pump mode at the time of the low frequency incident.

Depending on the under-frequency relay tripped and the mode of operation at the time of the frequency deviation, this service may be active during the transition from Normal to Emergency state, e.g. if units are already in turbine mode then they are dispatched to maximum generation by the time the frequency falls to 49.67Hz (Normal state), however, if in pump mode it has to fall to 49.20Hz to trigger the tripping of the pumps at which point an Emergency state is likely to be triggered if the frequency does not recover within 1 minute.

Turlough Hill's provision of operating reserve is procured by the TSO via a system services agreement for both generation and pump modes.

5.4.3. Active Power Set Points

In the synchronous area controlled by EirGrid all dispatchable generation and transmission connected demand is centrally controlled by the TSO, i.e. generation units are instructed from first sync and minimum generation level up to maximum export capability or any level in-between.

Additionally, GC CC.7.3.1.1 (v) specifies the TSO may request Automatic Generator Control (AGC) on certain generating units >60MW. AGC is a control system installed between the TSO and Generator whereby Active power set points can be adjusted remotely by the TSO. However, as part of the compliance activities for SOGL, specifically Article 145, both EirGrid and SONI have submitted a proposal to the regulatory authorities requesting not implement an automatic frequency restoration process (aFRP) where AGC would be required, ie. by referencing the frequency to control the generation output.

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However, EirGrid have remote control of the active power set points of a significant majority of all wind farms on the system as all new PPMs greater than 5MW are required to be Controllable PPMs, as are all new (unless derogated against) PPMs >1MW following approval of Version 6 of the Distribution Code in February 2020 These requirements are defined in the respective Distribution and Grid Codes.

While it may be necessary for a generator to synchronise or change their MW output the ultimate instruction would be to disconnect demand in response to a low frequency emergency or to disconnect generation for a high frequency emergency. This manual instruction is likely if the system frequency is an Emergency state but above the automatic triggering thresholds mentioned earlier, i.e. if below 49.50Hz and above the 48.85Hz LFDD threshold. Note that a high frequency Emergency state is from 50.50Hz and above this level then automatic OFGS is triggered. Therefore, the discussion on manual demand disconnection is covered in detail in section 5.8 as it is used not only for low frequency issues.

In accordance with NCER article 18(4) where SGUs are disconnected directly by the TSO in response to a frequency deviation as mentioned above; then the TSO shall prepare within 30 days a report detailing the rationale, implementation and impact of this action and submit it to the CRU.

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5.5. Voltage Deviation Management Procedure

[In accordance with EU NCER Article 19]

In accordance with NCER the Voltage Deviation Management procedures for the System Defence Plan are to be used when there is at least one violation of the voltage limits specified in SOGL, see section 3.4.2 for details.

5.5.1. Reactive power set points

When normal voltage increase techniques have been employed by the TSO (see section 3.4.2) and if the voltage is below normal system voltage range, additional voltage increase measures may be employed during the Emergency state:

- Dispatch out of merit generation to provide local MVArs
- Request neighbouring TSOs to provide additional MVArs
- Contact the DSO to determine the feasibility of blocking auto- transformers (fixed tap setting)

In the generic voltage control policy in accordance with Grid Code OC.4.4., the TSO has the ability to adjust the active MW set point to achieve a dynamic MVAr capability to deal with changing system conditions, OC.4.4.5.2 and OC.4.4.5.11 refers. Each generating unit must provide sustained operation of their reactive power capability (as required by CC.7.3.6) during transmission system disturbances across the full contingency voltage range specified by SOGL.

Additionally, Interconnectors and hence neighbouring TSO’s service provision is mandated in in the Grid Code (CC.7.5) and refers to the Interconnector Operating Protocol where specific services, including reactive power, are captured. GC CC.7.5.1.2 specifically refers to an Interconnector Operator co-operating with TSO for the development of procedures during system stress. OC.4.4.6.1.4 specifically states that Interconnector Operators may be requested, by agreement, to operate at MVAr levels outside their currently declared technical parameters. Neighbouring TSOs are obliged to meet the demands of the requesting TSO unless they are in Emergency state.

If the voltage has dropped below recommended levels, and there is no indication of a rapid improvement then load shedding will be considered by the TSO. Rapid load shedding is carried out by the DSO upon instruction from the TSO, see section 5.8 for manual demand disconnection details.

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5.6. Power Flow Management Procedure

[In accordance with NCER Article 20]

In accordance with NCER the Power Flow Management procedures for the System Defence Plan are to be used when there is at least one violation of the current limits in terms of thermal ratings specified for the individual plant and apparatus of the transmission system.

5.6.1. Active Power Set Points

Dispatch instructions are available to the TSO, where in the TSOs reasonable opinion, to ensure the security standards in accordance with SOGL are maintained, the TSO may also issue an Emergency Instruction (either pre- or post-fault) to a User in respect of any of its Plant. These will generally involve a dispatch instruction for an active (or reactive) power change (increase or decrease), or a change in required Notice to Synchronise (or, in the case of a demand unit or pump storage unit or energy storage unit, a change in the relevant effective time) in a specific timescale on an individual unit or groups of units. The TSO monitors all relevant plant to ensure they are being operated in compliance with the dispatch instruction, Grid Code OC10.4.4.1 and OC.10.4.5.2, refers, including where possible maintaining the active power set point as instructed until the TSO instructs again. Where, in the TSOs reasonable opinion, to ensure the security standards in accordance with SOGL are maintained, the TSO may also select a Special Protection Scheme for stability or thermal reasons, see next section.

The ultimate action is to disconnect a user to protect the transmission system and this may be carried out to prevent exceeding the thermal ratings of transmission system equipment, GC OC.6.7.4.1 (d) refers. The following clause in the GC, OC.6.7.4.2, includes for the TSO to instruct the DSO to disconnect a distribution system user. While an individual user or users may be disconnected to correct a specific overload, see Special Protection Schemes below, wider issues may be resolved using manual demand disconnection, see section 5.8.

In accordance with NCER article 20 (3) where SGUs are disconnected directly by the TSO in response to a thermal ratings issue as mentioned above; then the TSO shall prepare a report within 30 days detailing the rationale, implementation and impact of this action and submit this to the CRU.

5.6.2. Special Protection Schemes

These schemes are generally anti—islanding schemes to prevent a generator from being connected with insufficient load to provide a stable power island and load flow schemes to prevent thermal overloads. If the connection with the rest of the system is

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lost then the generator is inter-tripped to provide a safe shutdown and allow the TSO to restore the connection from the main interconnected system once the fault is cleared.

There is one example where a protection scheme is designed to protect the thermal rating of overhead line circuits and create two power islands which are each large enough to remain stable. This is the system separation protection scheme where the North-South 275kV double circuit tie-line between EirGrid and SONI is protected. There are two further 110kV North-South circuits that run in parallel and in normal operation the majority of the power flows are on the higher voltage circuits. The double circuit 275kV fault is a credible contingency which would result in unmanageable overloads on the 110kV circuits. Therefore, there is an inter-trip to the 110kV circuit breakers to ensure all four circuits are disconnected in the event of the double circuit fault. This results in the safe separation of the EirGrid and SONI systems and is one of the triggering events that leads to the declaration of an Emergency state.

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5.7. Assistance for Active Power Procedure

[In accordance with NCER Article 21]

In accordance with NCER, the Assistance for Active Power procedures for the System Defence Plan are to be used when there is an absence of control area adequacy in the day-ahead or intraday timeframe. For an Emergency state to be declared it is likely / imminent that in the period immediately ahead (i.e. in the next 4 hours) there is a high risk of failing to meet system demand.

Forecasting the system margin (or adequacy) is carried out in long term planning and an absence of margin may be declared up to the day ahead, based on scheduling runs, by issuing an Amber warning and declaring an Alert State to see if there is additional generation available, however, if the market fails to respond and an Emergency state is likely then the following additional procedures are available to the TSO.

5.7.1. Assistance for active power from SGU

All centrally dispatched generation units are by definition instructed by the TSO and are automatically available up to their declared Maximum Export Capacity (MEC). In addition the TSO has the ability to use Emergency Instructions, in accordance with Grid Code SDC2.A.11, which is a dispatch instruction to a generator which may require an action or response which is outside the limits implied by the then current declarations, e.g. to increase their output to the technical capability of the generator and the power system at that time.

In planning timescales all users are to co-operate in co-ordinating their outages to minimise the impact on the transmission system. The TSO may request at any time an alteration to the timing and duration of an outage of transmission connected generators plus the deferment of any maintenance, OC.2.6.2.1 and OC.2.7.2 refers. This will ensure that the TSO has the maximum available generation capability. This together with cancelling transmission outages removes any constraints to generators providing full output.

While currently all balancing service providers are centrally dispatched there may be future providers that are not. These are likely to be embedded in the DSO system, where the DSO shall co-operate with the TSO, DSU and Embedded Generators in all phases of outage planning to promote capacity adequacy, OC.2.7. 3 refers.

5.7.2. East West Interconnector (EWIC)

In accordance with the Interconnector Operating Protocol agreed with NGESO, EWIC is able to provide Emergency Assistance (EA). This is a service both to and from the neighbouring system which is an effective increase or decrease in active energy into the requesting TSO transmission system. It is envisaged that EA will be required in extreme

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cases when one of the parties foresees a difficulty in meeting the expected demand on its system, or foresees a difficulty in maintaining security on its transmission system. EA will be assumed available for each TSO to instruct unless specifically withdrawn or an EAS level other than Normal or Alert state is active.

The maximum available EA volume is 150MW and is capped by the Net Transfer Capacity declared at the time of the request, however, the request for EA must be met by the other party provided that the party providing the EA does not foresee, in meeting such a request, a difficulty in meeting the expected demand /in maintaining security on its own transmission system.

There are firm prices agreed for EA within the Balancing and Ancillary Services Agreement (BASA), which forms the binding agreement between the TSOs for financial reconciliation for energy differences from planned operation. Provision of EA is for a maximum of 2 hours unless otherwise agreed by both parties.

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5.8. Manual Demand Disconnection Procedure

[In accordance with EU NCER Article 22]

In accordance with NCER, the Manual Demand Disconnection procedures for the SDP are to be used when necessary to avoid prolonging an Emergency state.

Grid Code OC5 provides for the TSO to instruct demand control in general and applies to the TSO, DSOs and impacted demand customers (D-Code DOC5, refers). Demand control is concerned with the reduction of demand in the event of available generation being insufficient to meet demand, or in the event of breakdown or operating problems such as in respect of system frequency, voltage levels or thermal overloads on any part of the system.

The demand control arrangements may also apply where there is insufficient generation or transfers to meet demand in all or any part of another TSO's system where the TSO is able to assist the other TSOs. Please note the automatic demand control schemes and assistance with neighbouring TSOs are covered in a separate sections. 5.1 and 5.7 respectively.

For manual demand control this is specifically covered by Grid Code OC5.4, *Procedure for the implementation of Demand Control on the Instructions of the TSO*.
In the EirGrid business procedure there are listed three types of manual load shedding available to the TSO:

1. Emergency Load Shedding (5 minutes – 2 plans)
2. Emergency Load Shedding (30 minutes – 2 plans)
3. Rota Load Shedding

For the first type, the DSO would typically be on Amber alert with the load near the peak of the day and a major generation unit trips. The frequency is dropping and so under frequency tripping will start. If the TSO cannot recover the frequency it will instruct the DSO to run their first 5 minute plan. If the system cannot be stabilised, the TSO instructs the DSO to run their second 5 minute plan.

The DSO can shed approximately 200MW of load in each 5 minutes plan. Blocks of load within these limits (typically 50 MW) should be available so that shedding can occur on a phased basis. If this doesn't resolve the situation then the TSO will request the DSO to run part or all of the 30 minute emergency load shedding plans.

Following operational security analysis using the latest demand forecasts, if the TSO estimate that they will need to shed "X" MW of load before the peak; then 30 minute emergency load shedding may be instructed. This requirement is defined in blocks of

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50MW and is spread across the two plans. Each plan can shed up to 400 MW in 50 MW steps; therefore a total of 800 MW can be shed by the DSO in 30 minutes.

Both emergency load shedding facilities are available to the TSO to instruct as required. The 5 minute plan is primarily a subset of the overall combination of the 30 minute plan and so when the 5 minute plan is run and then the 30 minute plan is run, the maximum load shed would be 400MW per plan, i.e. 800 MW of load is available to be shed.

Where reasonable notice is available (at least 12 hours), the TSO will initiate Rota Load Shedding. The TSO and the DSO co-ordinate the plan, which provides for disconnection and reconnection of defined blocks of demand on instruction from the TSO. In this way the TSO can instruct the necessary level of disconnection (and reconnection) required by the circumstances at the time. The DSO shall comply with instructions issued by the TSO and in particular will not reconnect Demand other than in accordance with the TSO's instructions.

The Rota Load Shedding Plan provides for the issue of information to consumers through the media of the expected duration of Demand Control, and which blocks of consumers are at most risks of disconnection and at which times, based on a 3 hour cycle across 3 zones. Rota load shedding is based on a 3 zone / 3 hour cycle and is deployed where there is a continuous protracted deficit in generation availability. The objective is to share out the limited amount of electricity in the fairest possible way. Up to 25% of load is exempt and will not be shed.

Under the D-Code OC5.1.4 refers to exemptions that apply to vital and priority customers, such as critical national infrastructure or large industrial customers with safety and economic considerations.

In accordance with NCER article 22 (4) where demand is disconnected by the DSO as mentioned above; then the TSO shall prepare a report within 30 days detailing the rationale, implementation and impact of this action and submit this to the CRU.

Note that this forced demand disconnection is only introduced after all possible voluntary (contracted) demand disconnection has been exhausted. This SDP measure is proportionate, non-discriminatory and temporary.

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6. Next Steps

This concludes EirGrid's submission to the Commission for the Regulation of Utilities of the proposed design of system defence plan in accordance with Articles 11 and 4.5 of the Commission Regulation (EU) 2017/2196 establishing a network code on electricity emergency and restoration of the Commission Regulation (EU).

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