

Weekly Operational Constraints Update

Applicable from 07 February 2022 to 13 February
2022

(Week 6)

04 February 2022

Disclaimer

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Introduction

To enable the efficient and secure operation of the power system, EirGrid and SONI schedule and dispatch units so as to adhere to their respective Operating Security Standards¹. These standards ensure that the all-island transmission system is operated in a secure and reliable manner.

The process by which the TSOs schedule and dispatch the power system is outlined in the 'Balancing Market Principles Statement'². This includes a description of how the operational constraints outlined in this document are applied.

Weekly operational constraint document includes both long standing operational constraints and constraints that are updated on a weekly basis.

Weekly Operational Constraints

- The purpose of this Weekly Operational Constraints Update 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.
- In the analysis, a suite of N-1 contingencies are applied to the base case powerflow, and the resulting flows and voltages are compared against the Operational Security Standards. The N-1 contingencies include the tripping of each item of transmission plant and each generator transformer. Groups of generators / demand / wind etc. can be scaled up or down to determine a secure region of operation (known as transfer analysis or transaction analysis).
- The cases incorporate the latest generation and transmission outage information at the time of the study. This information is published on the EirGrid and SONI websites.
- Typically, from a dispatchable generation perspective the worst thermal constraints occur at peak system demand, and therefore only peak system demand scenarios are studied using transfer analysis. If required, other studies are performed, such as system demand valley where high voltages may be an issue.
- The wind levels in the various scenarios assume a flat profile across Ireland or Northern Ireland. We do not test Ireland wind levels above 2000 MW as, typically above these levels, constraints on dispatchable generation are not as binding due to the availability of the wind generation.
- The binding constraints on the flow on the North-South Tie Line from a thermal and voltage perspective tend to be due to thermal constraints on the Ireland side, save for specific Northern Ireland outages. This is why the Inter-Area Flow (North-South Tie Line Flow) Constraints Forecast below is only studied against Ireland wind generation.

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<http://www.soni.ltd.uk/media/documents/Operations/SONI%20Operating%20Security%20Standards%20v1.pdf>

https://www.eirgridgroup.com/site-files/library/EirGrid/EirGrid_Operating-Security-Standards_2021.pdf

² <https://www.eirgridgroup.com/site-files/library/EirGrid/EirGrid-and-SONI-Balancing-Market-Principles-Statement-V5.0.pdf>

- There may be other reasons, apart from voltage and thermal limits that lead to constraints, such as frequency, transient stability and adverse weather conditions. These are usually observed and dealt with close to real-time.
- Moyle Interconnector is limited to 270 MW export due to constraints on the Scotland side. National Grid plc performs daily studies to ascertain if and to what extent this can be increased. Please note that the figures below in relation to interconnectors pertain to the Ireland/Northern Ireland side only.
- Should any of the study assumptions materially change during the week, due to a forced outage for example, we will endeavour to perform new studies and publish results on the next working day.

Long Term Constraints

The Long Term Operational Constraints update presents the key system and generator constraints which are included in the scheduling process. The most common operational constraints that are modelled are:

- North – South tie-line export / import constraint
- Moyle import / export constraint
- Requirement to keep a minimum number of units on in an area
- Requirement to limit the output of the generators in an area to limit short circuit levels or overloads
- Requirement for a minimum output from the generators in an area to support the voltage or to avoid overloads

The Long Term Constraints update comprises of (i) Active Constraints, (ii) System Constraints, and (iii) Operating Reserve Requirements.

Weekly Operational Constraints

Generator and Transmission Outages

Generator and transmission plant outages as per published here:

[All-Island Generator Outages](#) – Under REMIT Publications

[Ireland Transmission Outages](#)

[Northern Ireland Transmission Outages](#)

Demand

All studies are performed at Weekday Peak System Demand unless otherwise stated

Jurisdiction	Weekday Peak System Demand (MW)	Weekend Peak System Demand (MW)
Ireland	5300	4900
Northern Ireland	1600	1325

Initial Interconnector and Tie Line Flows

	Flow (MW)
EWIC	At zero wind 250 MW Import (GB to IE) At 2000 MW wind 250 MW Export (IE to GB)
Moyle	N/A
North–South Tie Line Flow	0 MW Northern Ireland to Ireland / Ireland to Northern Ireland

The forecast constraints below are at Weekday Peak System Demand.

South Generation Constraints Forecast (TCG Type: MW; Limit Type B) as per Operational Constraints Update

Ireland Wind Generation (MW)	Minimum South Generation (MW)	Maximum South Generation (MW)
0	200	1650
1000	0	1650
2000	0	1650

Cork Generation Constraints Forecast (TCG Type: MW; Limit Type B) as per Operational Constraints Update

Ireland Wind Generation (MW)	Minimum Cork Generation (MW)	Maximum Cork Generation (MW)
0	0	1200
1000	0	1200
2000	0	1200

Inter-Area Flow (North-South Tie Line Flow) Constraints Forecast

Ireland Wind Generation (MW)	Maximum Northern Ireland to Ireland flow* (MW)	Maximum Ireland to Northern Ireland flow* (MW)
0	450	350 (Mon – Tue, Fri) 200 (Wed - Thu)
1000	450	400
2000	450	400

* These figures may change during real time system conditions

Ireland Wind Generation (MW)	Maximum EWIC Import (MW)*	Maximum EWIC Export (MW)*	Maximum Moyle Import (MW)*	Maximum Moyle Export (MW)*
0	500	530	442	400
1000	500	530	442	400
2000	500	530	442	400

* Values pertain to the Ireland/Northern Ireland side of the interconnectors only

Coolkeeragh C30 Running

Northern Ireland Wind Generation (MW)	Northern Ireland Demand (MW) above which C30 must be running with GT8 off	Northern Ireland Demand (MW) above which C30 must be running with GT8 operating as a synchronous compensator	Northern Ireland Demand (MW) above which C30 must be running with GT8 operating as a generator
0	1550	1608	Not required
450	Not required	Not required	Not required
900	Not required	Not required	Not required

Other Constraints/Notes/Risks

Should market participants identify operational risks related to COVID-19 they should inform the TSO as soon as possible via their normal point of contact. Should this instigate a significant change to scheduling and dispatch the TSOs will update this weekly constraints document to reflect this in a revised publication as soon as possible.

Jurisdiction	Constraint/Note	Reason
Ireland / Northern Ireland	Winter transmission ratings are in place.	Seasonal.
Ireland / Northern Ireland	EirGrid and SONI will, subject to system conditions, provide additional notice of intended unit synchronisation and desynchronisation decisions to facility operators in order to accommodate their amended operational practices.	COVID-19 has resulted in restrictions in working arrangements at some generation facilities.
Ireland / Northern Ireland	Update to System Wide Transmission Constraint Group: Operational Limit for Rate of Change of Frequency (S_RoCoF) Limit Type: X:<= Limit: 1 Hz/s	Continued trialling of an increased system limit for the Rate of Change of Frequency (RoCoF). System conditions permitting, the RoCoF limit will be 1.0 Hz/s.
Ireland	One of the following units are must run for security of supply, when available: MP1, MP2, MP3.	Security of Supply.
Ireland / Northern Ireland	Update to System Wide Transmission Constraint Group: Operational Limit for Non-Synchronous Generation (S_SNSP_TOT) Limit X<=75%	Trialling of 75% SNSP limit commenced 22 nd April 2021.

Long Term Operational Constraints

List of Terms

Transmission Constraint Group (TCG) Type	
MW	Limit MW output of unit or units assigned to a TCG
MWR	Limits (the total MW + Primary Reserve - the area demand) from assigned resources
NB	Limit to the status (On/Off) of the unit or units assigned to a TCG

Limit Flag	
E	Equality Constraint (generation = load)
X	Export Constraint - limit output of a group of units \leq max limit
N	Import Constraint - limit output of a group of units \geq min limit
B	In-between Constraint; \geq min and \leq max

The following tables set out the system constraints:

- Active System Wide Constraints;
- Active Northern Ireland Constraints, and
- Active Ireland Constraints.

Note that the limits specified in each table represent the normal intact transmission network limit. These limits may vary from time to time due to changing system conditions.

Active System Wide Constraints

Name	TCG Type	Limit Type	Limit	Resources	Description
Inter-Area Flow (S_MWR_ROI)	MWR	X:< =	400 MW (There is a margin of 20MW on this limit for system safety)	Ireland and Northern Ireland Power Systems	Ensures that the total MW transferred from Ireland to Northern Ireland does not exceed the operational limits of the North-South tie line. It takes into account the rescue/reserve flows that could occur immediately post fault inclusive of operating reserve requirements. This is required to ensure the operational limits of the existing North South tie line are respected.
Inter-Area Flow (S_MWR_NI)	MWR	X:< =	450 MW (There is a margin of 20MW on this limit for system safety)	Ireland and Northern Ireland Power Systems	Ensures that the total MW transferred from Northern Ireland to Ireland does not exceed the limitations of the North-South tie line. It takes into account the rescue/reserve flows that could occur immediately post fault inclusive of operating reserve requirements. This is required to ensure the limits of the existing North South tie line are respected.
Non-Synchronous Generation (S_SNSP_TOT)		X:< =	70%	Wind, PV, Moyle Interconnector, EWIC Interconnector	Ensures that the SNSP is kept below 70%. Please note that the TSOs on 22nd April 2021 commenced a 75% SNSP trial.
Operational Limit for RoCoF (S_RoCoF)		X:< =	0.5 Hz/s	Ireland and Northern Ireland Power Systems	Ensures that RoCoF does not exceed 0.5 Hz/s. Please note that the TSOs on 17 th June 2020, started a 1 Hz/s RoCoF trial
Operational Limit for Inertia (S_INERTIA_TOT)		N:> =	23,000MWs	Ireland and Northern Ireland Power Systems	Ensures that all island Inertia does not fall below 23,000 MWs.

Active Northern Ireland Constraints

Name	TC G Type	Limit Type	Limit	Resources	Description
System Stability (S_NBMIN_MINNIU)	NB	N:>=	3 Units at all times	B10, B31, B32, C30, K1, K2	There must be at least 3 machines on-load at all times in Northern Ireland. Required for dynamic stability.
System Stability (S_NBMIN_MINNI1)	NB	N: >=	Minimum 1 at all times	K1, K2, C30	Security of supply.
Replacement Reserve (S_REP_NI) (S_MWMAX_NI_GT)	MW	X:<=	272 MW	BGT1, BGT2, CGA, CGT8, EMPOWER, iPOWER, KGT1, KGT2, KGT3, KGT4	Combined MW output of OCGTs and AGUs must be less than 272 MW (out of a total of 397 MW) in Northern Ireland at all times. 125 MW required for replacement reserve. The limit is subject to change based on the availability of the units and transmission constraints that may limit their output.
North West Generation (S_NBMIN_CPS)	NB	N:>=	0 or 1 Unit depending on NI system demand	C30	Coolkeeragh C30 must be on load when the NI system demand is at or above 1,550 MW, CGT8 is unavailable and NI wind generation < 450 MW. This demand limit can be raised to 1,608 MW if CGT8 is available. For NI wind generation in excess of 450 MW there is no constraint. This operational constraint is required to ensure voltage stability in the northwest of Northern Ireland and to prevent possible system voltage collapse above the indicated system demand.

Moyle Interconnector (S_MWMIN_MOYLE) (S_MWMAX_MOYLE)	MW	B	-400* < MW < 442	Moyle Interconnector ³	<p>It ensures that all flows do not exceed an import of 442 MW to Northern Ireland and an export of 400 MW* to Scotland (values taken from NI). This is required to ensure that the limits are respected.</p> <p>*Notes:</p> <ol style="list-style-type: none"> 1. Firm export limit on Moyle increased to 250MW from 80MW on 1st December 2020. There is an agreed process between Moyle and NGET on releasing additional “non-firm” export capacity when GB system conditions allow. 2. BREXIT - Impact on Scheduling Day-Ahead Markets, effective from 31 December 2020, will not include any SEM-GB interconnection capacity. This first day ahead LTS run should be considered more indicative than it would normally be, given that firm interconnector schedules for the first part of the next day (from 23:00 D-1 to 11:00 D) will not be available until post IDA1 (after 18:10). The LTS that is published each evening post IDA1 will reflect the firm interconnector schedules.
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³ Combined Ramp Rate of EWIC and Moyle Interconnectors is limited to 10 MW/Min

Active Ireland Constraints

- Scenario A: In this scenario if PBA or PBB are operating in combined cycle mode they will be considered as constraint resources
- Scenario B: In this scenario if PBA or PBB are configured to synchronise in 10 minutes they will be considered as constraint resources

Name	TCG Type	Limit Type	Limit	Resources	Description
System Stability (S_NBMIN_ROImin)	NB	N:>=	5 Units	AD2, DB1, GI4, HNC, HN2, MP1, MP2, MP3, PBA ☐, PBB ☐, TB3, TB4, TYC, WG1	There must be at least 5 machines on-load at all times in Ireland. Required for dynamic stability. ☐ See Scenario A
Replacement Reserve (S_REP_ROI) (S_MWMAX_ROI_GT)	MW	X:<=	698 MW ☐	AT1, AT2, AT4, ED3, ED5, RP1, RP2, TP1, TP3. PBA ☐, PBB ☐	Combined MW output of OCGTs must be less than 698 MW (out of a total of 1023 MW) in Ireland at all times. 325 MW required for replacement reserve. The limit is subject to change based on the availability of the units and transmission constraints that may limit their output. ☐ See Scenario B
Dublin Generation (S_NBMIN_DubNB2)	NB	N:>=	1 Units	DB1, HNC, HN2	There must be at least 1 large generator on-load at all times in the Dublin area. Required for voltage control.
Dublin Generation (S_NBMIN_Dub_NB)	NB	N:>=	2 Units	DB1, HNC, HN2, PBA ☐, PBB ☐	There must be at least 2 large generators on-load at all times in the Dublin area. Required for voltage control. This assumes EWIC is operational. Note that during an outage of EWIC there must be at least 3 large generators on-load at all times in the Dublin area. ☐ See Scenario B
Dublin Generation (S_NBMIN_DUB_L1)	NB	N:>=	2 Units if Ireland System Demand >4000MW	DB1, HNC, PBA ☐, PBB ☐,	Requirement for 2 units to be on load when Ireland System Demand is greater than 4000 MW. This operational constraint is required for

Name	TCG Type	Limit Type	Limit	Resources	Description
					load flow control in the Dublin area. This assumes EWIC is operational. <input type="checkbox"/> See Scenario B
Dublin Generation (S_NBMIN_DUB_L2)	NB	N:>=	3 Units if Ireland System Demand > 4700 MW	DB1, HNC, HN2, PBA <input type="checkbox"/> , PBB <input type="checkbox"/>	Requirement for 3 units to be on load when Ireland System Demand is greater than 4700 MW. This operational constraint is required for load flow control in the Dublin area. This assumes EWIC is operational. <input type="checkbox"/> See Scenario B
South Generation (S_NBMIN_STHLD1)	NB	N:>=	1 Unit if Ireland System Demand > 1500 MW	AD2, AT1, AT2, AT4, SK3, SK4, WG1	Requirement for at least one Unit to be on load when Ireland System Demand is greater than 1500 MW. This operational constraint is required for voltage stability in the South.
South Generation (S_NBMIN_STHLD2)	NB	N:>=	2 Units if Ireland System Demand > 2500 MW 3 Units if Ireland System Demand > 3500 MW	AD2, AT1, AT2, AT4, GI4, SK3, SK4, WG1	Requirement for at least two Units, to be on load when Ireland System Demand is greater than 2500 MW. Requirement for at least three Units, to be on load when Ireland System Demand is greater than 3500 MW. This operational constraint is required for voltage stability in the South.
South Generation (S_NBMIN_STHLD3)	NB	N:>=	1 Unit if Ireland System Demand > 2500 MW	AD2, AT1, AT2, AT4, GI4, WG1	Requirement for at least one Unit to be on load when Ireland System Demand is greater than 2500 MW. This operational constraint is required for voltage stability in the South.
South Generation (S_NBMIN_STHLD4)	NB	N:>=	1 Unit if Ireland System Demand > 3500 MW AND	AD2, AT1, AT2, AT4, WG1	Requirement for at least one Unit to be on load when Ireland System Demand is greater than 3500 MW AND Ireland Wind total is below 500 MW. This operational

Name	TCG Type	Limit Type	Limit	Resources	Description
			Ireland Wind < 500 MW		constraint is required for voltage stability in the South.
South Generation (S_NBMIN_STHLD5)	NB	N:>=	1 Unit if Ireland System Demand > 4200 MW	AD2, GI4, WG1	Requirement for at least one Unit to be on load when Ireland System Demand is greater than 4200 MW. This operational constraint is required for voltage stability in the South.
Cork Generation (S_MWMIN_CRK_MW) (S_MWMAX_CRK_MW)	MW	B	0 MW <MW< 1200 MW	AD2, AT1, AT2, AT4, WG1	Generation restriction in the Cork area: this will be determined week ahead and available in the Weekly Operational Constraints Update.
South Generation (S_MWMIN_STH_MW) (S_MWMAX_STH_MW)	MW	B	0 MW <MW< 1800 MW	AD2, AT1, AT2, AT4, GI4, WG1	Generation restriction in the Southern Region: this will be determined week ahead and available in the Weekly Operational Constraints Update.
400 kV Network (S_NBMIN_MP_NB)	NB	N:>=	1 unit when Ireland wind < 1,000 MW	MP1, MP2, MP3, TYC	There must be at least one unit on load at all times; required to support the 400kV network.
EWIC Interconnector (S_MWMIN_EWIC) (S_MWMAX_EWIC)	MW	B	-526 <MW< 504	EWIC Interconnector ⁴	It ensures that all flows do not exceed an import of 504MW to Ireland and an export of 526MW to GB (values taken from Portan). This is required to ensure that the limits are respected. Note: BREXIT - Impact on Scheduling Day-Ahead Markets, effective from 31 December 2020, will not include any SEM-GB interconnection capacity. This first day ahead LTS run should be considered more indicative than it would normally be, given that firm interconnector schedules for the first

⁴ Combined Ramp Rates on EWIC and Moyle Interconnectors are limited to 10 MW/Min

Name	TCG Type	Limit Type	Limit	Resources	Description
					<p>part of the next day (from 23:00 D-1 to 11:00 D) will not be available until post IDA1 (after 18:10). The LTS that is published each evening post IDA1 will reflect the firm interconnector schedules.</p>
<p>South West Generation (S_NBMIN_SWENB2)</p>	NB	N:>	1 Unit	AD2, WG1	<p>To support South-West voltage, at times of low demand and very low wind generation output in the South-West, additional generation may be required.</p>

System Constraints

Tie Line Limits

Tie line flows in both directions have physical limits, the maximum flow that can be sustained without breaching system security rules (line overloads, voltage limits, system stability etc.) after a credible transmission or generation event. The limits are referred to as the Total Transfer Capacity (TTC) comprising of two values: N-S and S-N. For more information on Inter-Area Flow (North-South Tie Line) Constraints follow link:

https://www.sem-o.com/documents/general-publications/Information_Note_on_Inter-Area_Flow_Constraints.pdf

Non-Synchronous Generation

To ensure the secure, stable operation of the power system, it is necessary to limit the level of non-synchronous generation of the system. The System Non-Synchronous Penetration (SNSP) is a measure of the non-synchronous generation on the system at an instant in time i.e. the non-synchronous generation and net interconnector imports as a percentage of the demand and net interconnector exports (where “Demand” includes pump storage consumption when in pumping mode).

Ramping Margin Constraints

The Ramping Margin Constraints maintain a level of dispatchable generation and demand to mitigate renewable forecast error.

Classification	Category	Delivered within	Maintained for
Ramping Margin	Ramping Margin 1 (RM1)	1 Hours	2 Hours
	Ramping Margin 3 (RM3)	3 Hours	5 Hours
	Ramping Margin 8 (RM8)	8 Hours	8 Hours

Ramping Margin 1 is the increased MW output or reduction in demand, a unit can provide, within one hour of receiving a dispatch instruction and maintaining that MW output for a further two hours after the one hour period has elapsed.

Ramping Margin 3 is the increased MW output or reduction in demand, a unit can provide, within three hours of receiving a dispatch instruction and maintaining that MW output for a further five hours after the three hour period has elapsed.

Ramping Margin 8 is the increased MW output or reduction in demand, a unit can provide, within eight hours of receiving a dispatch instruction and maintaining that MW output for a further eight hours after the eight hour period has elapsed.

Adverse Weather and Increased System Risk

During periods of adverse weather or where there is an increased system risk (e.g. high impact generator or interconnector testing), the TSOs may implement measures to mitigate the consequences of this risk. Such measures may include but not limited to scheduling additional reserve and running units out of merit.

There are changes to operational constraints at present associated with the Covid-19 pandemic. These are highlighted in the Run Hours constraints for Ireland and N. Ireland. It is of

critical importance that the security of the power system is maintained during the Covid-19 pandemic period.

As such, the TSOs are aware that Covid-19 may have implications for market participants during the pandemic period.

Should market participants identify operational risks related to Covid-19 they should inform the TSO as soon as possible via their normal point of contact. Should this instigate a significant change to scheduling and dispatch the TSOs will update this weekly constraints document to reflect this in a revised publication as soon as possible.

Any changes to operational constraints will be notified through the Weekly Operational Constraints Process.

Operating Reserve Requirements

The following tables show the operating reserve requirements on an all-island basis and in each jurisdiction.

Category	All Island Requirement % Largest In-Feed	Ireland Minimum ¹ (MW)	Northern Ireland Minimum (MW)
POR	75% ³ (S_PRM_TOT)	155/ 150 (S_PRM_ROI)	50 (S_PRM_NI)
Regulating Sources POR ²		75/ 75 (S_PRM_ROI)	50 (S_PRM_NI)
SOR	75% ⁴ (S_SEC_TOT)	155/ 150 (S_SEC_ROI)	50 (S_SEC_NI)
TOR1	100% (S_TR1_TOT)	155/ 150 (S_TR1_ROI)	50 (S_TR1_NI)
TOR2	100% (S_TR2_TOT)	155/ 150 (S_TR2_ROI)	50 (S_TR2_NI)

1. Ireland Lower values apply for when there is at least one pump storage unit in pump mode.
2. Minimum values of POR in each jurisdiction must be supplied from regulating sources
3. At times more than 75% POR is held All Island (up to 80%) in order to maintain system security standards based on transient security analysis (this will remain under review by the TSOs).
4. At times more than 75% SOR is held All Island (up to 100%) in order to maintain system security standards based on real-time transient security analysis (this will remain under review by the TSOs).

Operating Reserve Definitions

Classification	Category	Delivered By	Maintained Until
Frequency Containment Reserves	Primary (POR)	5 seconds	15 seconds
	Secondary (SOR)	15 seconds	90 seconds
Frequency Restoration Reserves	Tertiary 1 (TOR1)	90 seconds	5 minutes
	Tertiary 2 (TOR2)	5 minutes	20 minutes

Frequency Containment Reserves (FCR) means the active power reserves available to contain system frequency after the occurrence of an imbalance, and for EirGrid and SONI shall include Primary Operating Reserve (POR) and Secondary Operating Reserve (SOR) as defined in the EirGrid and SONI Grid Codes.

Frequency Restoration Reserves (FRR) means the active power reserves available to restore system frequency to the nominal frequency, and for EirGrid and SONI shall include Tertiary Operating Reserve 1 (TOR 1) and Tertiary Operating Reserve 2 (TOR 2) as defined in the EirGrid and SONI Grid Codes.

Replacement Reserves (RR) means the active power reserves available to restore or support the required level of FRR to be prepared for additional system imbalances, including generation reserves. For the IE/NI synchronous area to progressively restore the activated FCR and FRR, and for EirGrid and SONI shall include Replacement Reserve as defined in the EirGrid and SONI Grid Codes.

Source of Reserve

	Ireland	Northern Ireland
Regulating Reserve	Synchronised Generating Units	Synchronised Generating Units
Non or Partially Regulating Reserve Please Note: Since 1 st April 2021 the TSOs are operating the battery portfolio on a trial basis which will evolve as the TSOs' operational experience, business processes and IT tools mature.	Turlough Hill Units when in pumping mode 45 MW of Response from DSUs EWIC Interconnector (up to 75 MW) 168 MW of battery response	60 MW of battery response 5 MW of Response from DSUs Moyle Interconnector (up to 75 MW)
Negative Ramping Reserve Please Note: From 14th of January 2021 the negative reserve trial completed resulting in a permanent reduction of the requirement in Ireland from 100MW to 0MW.	0 MW (Defined as the MW output of a conventional generator above its minimum load which can be delivered at or above 5 MW/min)	50 MW (Defined as the MW output of a conventional generator above its minimum load which can be delivered at or above 5 MW/min)