All-Island Transmission System Performance Report

2018

SONI EIRGRID

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1. Introduction

EirGrid and SONI, as Transmission System Operators (TSOs) for Ireland and Northern Ireland respectively, are pleased to present the annual Transmission System Performance Report for 2018. This report contains transmission system data and performance statistics for the transmission system in Ireland and Northern Ireland for the year 2018 (01 January 2018 – 31 December 2018).

EirGrid is required to publish an annual report on the performance of the TSO business in accordance with Condition 18 of the Transmission System Operator Licence granted to EirGrid by the Commission for Regulation of Utilities (CRU).

Similarly, SONI is required to produce an annual report on the performance of the TSO business in accordance with Condition 20 of the Licence to participate in the Transmission of Electricity granted to SONI Ltd by the Department for the Economy.

This report contains high-level transmission system characteristics and a detailed breakdown of key figures along with an explanation of what these figures mean for the all-island transmission system in the coming year and into the future. Through comparison with previous reports, this report provides a useful resource through which possible trends can be identified.

This report is structured as follows:

- Section 3 outlines all-island system data, generation availability and outages,
- Section 4 details the performance of the EirGrid TSO business during 2018 against the criteria approved by the CRU,
- Section 5 details the performance of the SONI TSO business during 2018 against the criteria approved by The Utility Regulator in Northern Ireland.

Appendices which provide further detail on the data, results and methodology of relevance are included at the end of this report.

2. Executive Summary

The annual Transmission System Performance Report for 2018 is a comprehensive review of the transmission system through which EirGrid and SONI make available key all-island system operating data from the previous year.

Key statistics detailed in this report include:

- All-Island Generation Statistics
- Transmission System Availability Statistics for Ireland and Northern Ireland
- Details on System Events leading to System Minutes Lost
- Details of All-Island System Frequency Events

KEY DATA

All-island

- All-island peak demand reached 6,508 MW on 04 December 2018. The minimum all-island demand was 2,520 MW and occurred on 27 May 2018.
- The all-island installed capacity of conventional generation in 2018 was 8,548 MW.
- In 2018 the system frequency was operated within 49.9 Hz and 50.1 Hz for 99.65% of the time.
- There were no major incidents in 2018. A major incident is one which results in the loss of greater than or equal to one system minute as a result of a single system disturbance.

Ireland

- In 2018 the availability of the East West Interconnector was 87%.
- The average availability of the Ireland transmission system in 2018 was 95.5%.
- The System Minutes lost for 2018, attributable to EirGrid, was 0.411.

Northern Ireland

- The availability of the Moyle Interconnector for 2018 was 99.63%.
- The average availability of the Northern Ireland transmission system in 2018 was 96.5%.
- The System Minutes lost for 2018, attributable to SONI, was 0.622.

3. All-Island System Data

3.1 Overview of the All-Island Electricity System

The transmission system in Ireland and Northern Ireland provides the means to transport energy from generators to demand centres across the island. The transmission system is comprised of high-voltage overhead lines and cables that connect power stations, interconnectors and substations. Transformers link different voltage levels and provide a path for power to flow from higher to lower voltage networks. The transmission system in Ireland is operated at 400 kV, 220 kV and 110 kV. The transmission system in Northern Ireland is operated at 275 kV and 110 kV.

The 400 kV, 275 kV and 220 kV networks form the backbone of the transmission system. They have higher power carrying capacity and lower losses than the 110 kV network.

The Ireland and Northern Ireland transmission systems are electrically connected by means of one 275 kV double circuit. This connection is from Louth station in Co. Louth (IE) to Tandragee station in Co. Armagh (NI).

There are also two 110 kV connections:

- Letterkenny station in Co. Donegal (IE) to Strabane station in Co. Tyrone (NI)
- Corraclassy station in Co. Cavan (IE) to Enniskillen station in Co. Fermanagh (NI)

This section contains basic all-island transmission system data. Further information can be found on the EirGrid Group website: www.eirgridgroup.com.

3.2 Total System Production

Total exported energy takes into account energy supplied by large-scale and some small-scale generation[1] as well as pumped storage units on the island. This does not take into account interconnector imports and exports.

Table 1: Total Exported Energy 2017 & 2018

	2017	2018
All-Island Total Exported Energy [GWh]	37,856	36,996
Ireland Total Exported Energy [GWh]	29,129	28,823
Northern Ireland Total Exported Energy [GWh]	8,727	8,173

[1] Small-scale generation that is modelled in our Energy Management System, typically ≥ 5 MW

3.3 System Records

Peak demand is a measure of the maximum demand on the transmission system over a particular period (e.g. annual or seasonal) and is a key measurement for any power system. The transmission system in Ireland and Northern Ireland is a winter peaking system as a result of greater heating and lighting requirements during the winter months. The all-island winter peak in 2018 was 6,508 MW and occurred at 17:15 on 04 December.

In summer, the reduced need for heating and lighting results in a lower demand for electricity. The minimum demand is known as the 'minimum summer night valley' and in 2018 a minimum all-island demand of 2,520 MW was recorded at 05:30 on 27 May.

The installed wind capacity continues to increase year-on-year, enabling Ireland and Northern Ireland to progress towards the target of having 40% of our electricity produced by renewable sources by 2020. From the installed wind capacity, a peak all-island wind generation output of 3,990 MW was achieved on 12 December. Table 2 provides a summary of the system records for 2017 and 2018.

Table 2: System Records 2017 & 2018

	2017	2018
Winter Peak Demand [MW]	6,531	6,508
Minimum Summer Night Valley [MW]	2,427	2,520
Maximum Wind Generation [MW]	3,297	3,990

3.4 Generation Capacity

Generating plant is connected to both the transmission and distribution systems. All generation contributes to meeting system demand. The total generation capacity is calculated as the sum of all fully operational generator capacities connected to both systems[2].

The all-Island installed capacity of conventional generation in December 2018 was 8,548 MW (6,414 MW in Ireland and 2,133 MW in Northern Ireland). By December 2018, contributions towards the capacity margins from demand side units (DSUs) were 400 MW in Ireland and 92 MW in Northern Ireland. There was also 89 MW of aggregated generating units (AGUs) that contributed towards the capacity margin in Northern Ireland. This does not include any import capacity from the Moyle Interconnector or the East West Interconnector.

[2] Fully operational generator capacity is given by the Maximum Export Capacity (MEC) of the generator.

The all-island installed capacity of wind generation in 2018 was 4,942 MW (3,666 MW in Ireland and 1,276 MW in Northern Ireland).

Appendix 3 provides a list of the fully dispatchable generating units connected to the transmission system.

3.5 Generation Availability

Generation Availability is a measure of the capability of a generator to deliver power in a given period to the transmission system. In order for EirGrid and SONI to operate a secure and reliable transmission system in an economic and efficient manner, it is necessary for generators to maintain a high rate of availability.

Generation system availability is calculated on a daily and 365-day rolling average basis[3]. Figure 1 shows the daily and 365-day rolling average availability for 2018.

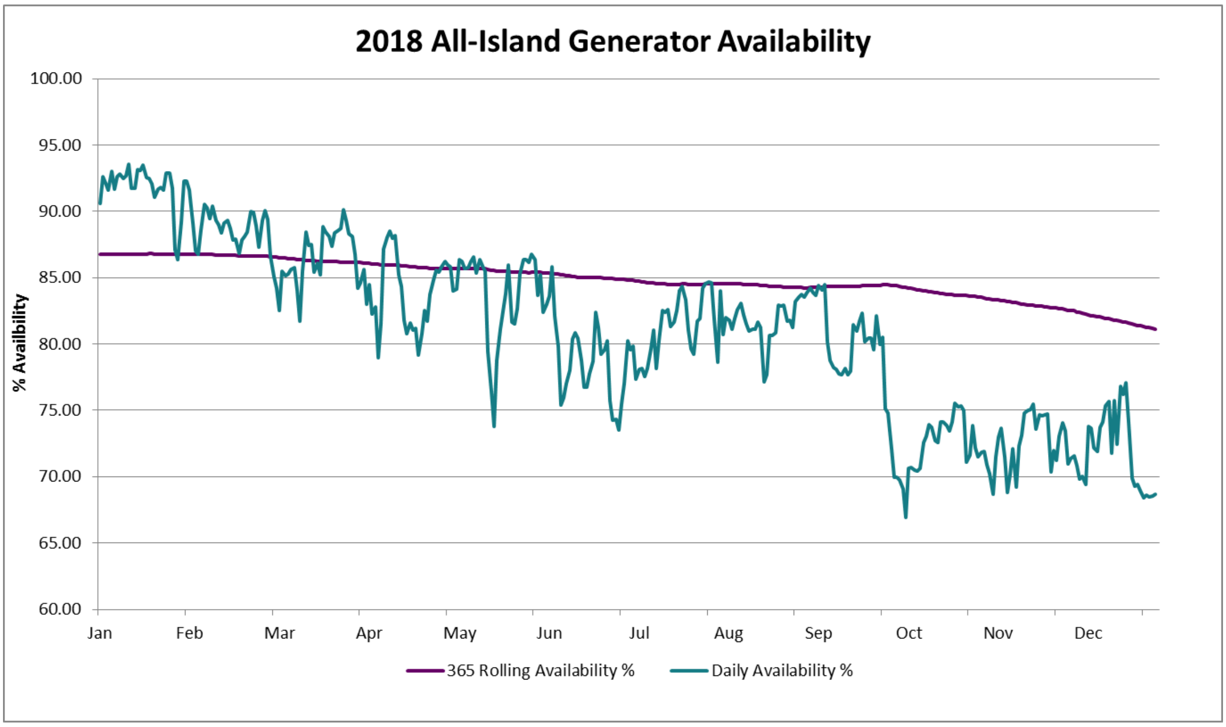

Figure 1: Generation System Availability 2018

- The average daily generation system availability in 2018 was 81.1%.
- The maximum daily generation system availability in 2018 was 93.5%.
- The minimum daily generation system availability in 2018 was 66.9%.

[3] 365-day rolling average is a capacity weighted average availability over the previous 365 days.

3.6 Generation Forced Outage Rate

The generation forced outage rate (FOR) is calculated on a daily and rolling 365-day average basis. The daily FOR is a capacity weighted percentage of the time during the day that generation units are unavailable due to unforeseen/unplanned outages. The 365-day rolling FOR is the average of the daily FOR over the previous 365 days. The daily FOR and 365-day rolling FOR are shown in Figure 2.

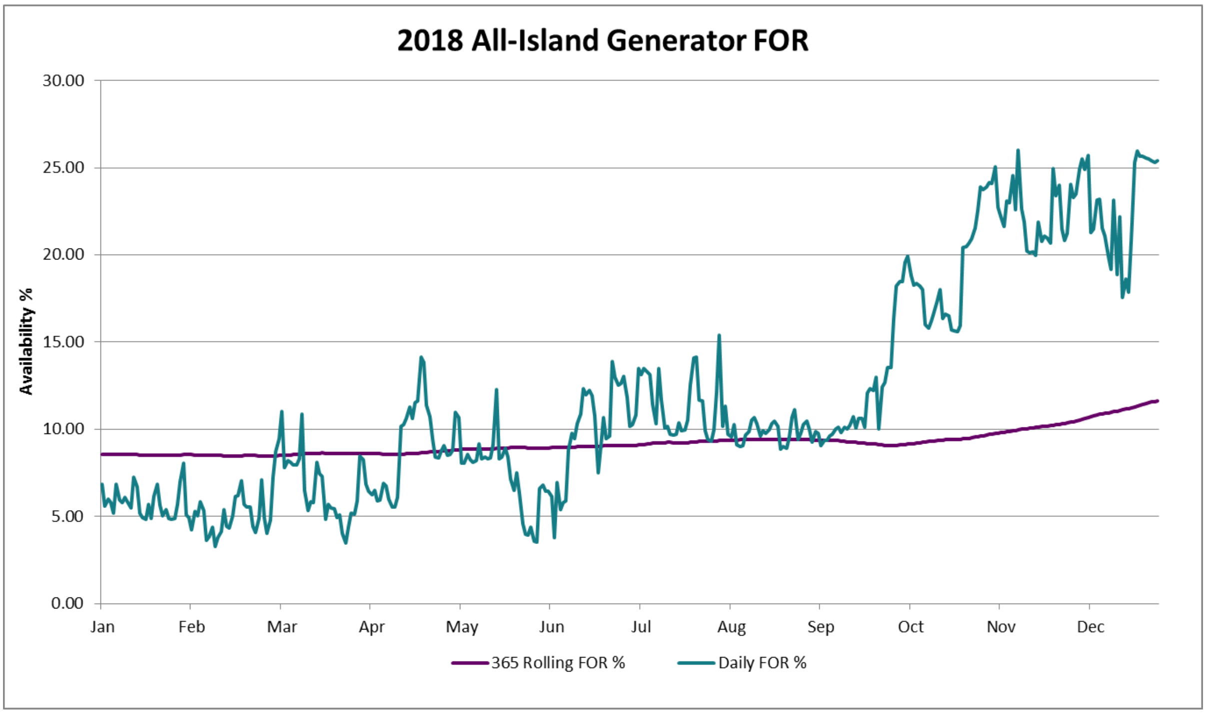

Figure 2: Generation System Forced Outage Rate 2018

- The average daily generation system forced outage rate in 2018 was 11.6%.
- The maximum daily generation system forced outage rate in 2018 was 26.0%.
- The minimum daily generation system forced outage rate in 2018 was 3.3%.

3.7 Generation Scheduled Outage Rate

The generation scheduled outage rate (SOR) can be calculated on a daily and rolling 365-day average basis. The daily SOR is a capacity weighted percentage of the time during the day that generation units are unavailable due to planned outages. The 365-day rolling SOR is the average of the weekly SOR over the previous 365 days. The daily SOR and 365-day rolling SOR are shown in Figure 3.

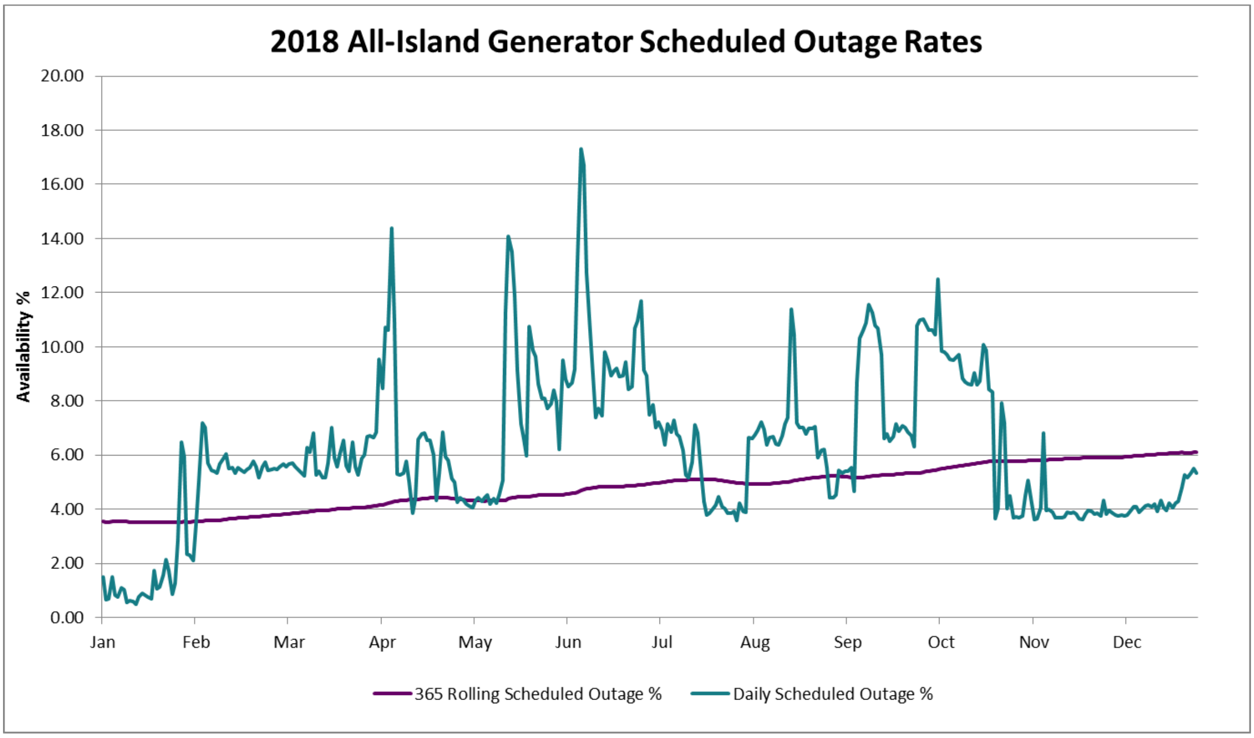

Figure 3: Generation System Scheduled Outage Rate 2018

- The average daily generation system scheduled outage rate in 2018 was 6.1%.
- The maximum daily generation system scheduled outage rate in 2018 was 17.3%.
- The minimum daily generation system scheduled outage rate in 2018 was 0.5%.

4. EirGrid Transmission System Performance

This section relates to the performance of EirGrid TSO and the transmission system in Ireland only, unless explicitly stated otherwise. This data has been prepared by EirGrid in accordance with the requirements of Part 5 of Condition 18 of its Transmission System Operator Licence.

4.1 Summary

There were no major incidents in 2018. A major incident is one which results in the loss of greater than or equal to one system minute as a result of a single system disturbance.

The system minutes lost as a result of faults on the main system was 0.411 in 2018. No system minutes were lost due to the disconnection of normal tariff load customers during Under Frequency Load Shedding (UFLS) disturbances.

EirGrid have a target to operate the system frequency within the range 49.9 Hz to 50.1 Hz for 94% of the time. In 2018, the system frequency was within the agreed limits 99.65% of the time.

4.2 Grid Development and Maintenance

This section provides an overview of grid development activities in 2018.

4.2.1 Completed Capital Projects

The following capital projects were completed in 2018:

- Ardnacrusha 110 kV Station Refurbishment and Busbar Uprate
- Knockacummer Windfarm Permanent Connection
- Great Island 110 kV Station Refurbishment
- Bellacorick - Castlebar 110 kV Line Uprate (Part 2)
- Cathaleen's Fall 110 kV Station Busbar Uprate
- Cauteen - Tipperary 110 kV Line Uprate
- Poolbeg 220 kV Station Installation of 2 x 50 Mvar Reactive Support

- Fencing and Bunding at Poolbeg 220 kV Station
- Castlebar 110 kV Station (Transmission works associated with 38 kV GIS)
- Dungarvan 110 kV Station (Transmission works associated with 38 kV GIS)
- Surge Arrestor Replacement – Northern Region
- Transmission Tower Painting – Northern Region
- Raffeen - Trabeg 1 110 kV Line Uprate - Internal Line Work
- Carrick-on-Shannon 110 kV Circuit Breaker Replacements
- Carrick-on-Shannon - Arigna T - Corderry 110 kV Line Uprate
- Knockalough Windfarm Shallow Works
- Bandon - Raffeen 110 kV No. 1 Line Refurbishment
- Meath Hill Windfarm 110 kV Station Shallow Works
- Slievecallan Windfarm 110 kV Station Shallow Works
- Cloon - Lanesboro Diversion - Kilroy
- Snugborough 110 kV Station
- Kelwin Wind Farm / Coolnanoonagh 110 kV Station Shallow Works
- Dunstown DC Systems
- Oldstreet Tynagh 220 kV Line Fibre Wrap

4.2.2 New Connection Offers

Parties seeking a new connection to the transmission system must apply to EirGrid for a connection offer. EirGrid operates within a regulatory approved process for providing connection offers to generators and demand customers seeking direct connection to the transmission system. The process for issuing generation offers was consulted on in 2017 resulting in the Enduring Connection Policy which will lead to a significant increase in the number of new generation capacity offers issuing in 2019.

In order to connect to the transmission system, all demand and generation customers must execute a connection agreement with EirGrid. Table 3 summarises the total number of new capacity connection agreements executed in 2018 and their associated load or generation capacities. A connection offer which is accepted in one year is unlikely to impact on connected generation capacity in the same year given the lead times associated with construction.

Table 3: New Capacity Executed Demand & Generation Connection Agreements

	Demand	Generation
Executed Connection Offer Agreements in 2018 [No.]	1	12
Executed Connection Offer Agreements in 2018 [Capacity]	142 MVA	626 MW

In addition to issuing connection offers for new generation and demand capacity, EirGrid facilitates existing contracted customers in modifying existing connection agreements. This represents a significant workload particularly as project reach project milestones nearing connection.

4.2.3 Connections Energised

When a connection agreement is executed for a new connection, it typically takes a number of years before the demand or generation is connected to the transmission system. This period includes project development, time taken to obtain consents and to construct the connection.

When the transmission connection is energised, it then takes a number of months for the generator to reach commercial operation. This period is generally much shorter for demand customers.

Table 4 provides an overview of the number of new connections to the transmission system commissioned in 2018.

Table 4: Demand & Generation Connections Energised in 2018

	Demand	Generation	WFPS & PV[4]
Connections Energised in 2018 [No.]	1	0	14
Connections Energised in 2018 [Capacity]	22 MVA	0 MW	315.6 MW

4.2.4 Customers Certified Operational

Table 5 provides an overview of customers connected to the transmission system who have been deemed fully operational. It shows customer connections which have completed the testing phase and have received an operational certificate from EirGrid. This includes

[4] WFPS: Wind Farm Power Station, PV: Photovoltaic.

generators connected to the distribution network. Note that demand customers are not currently certified by EirGrid and are therefore not included in the table.

Following energisation, the unit is required to complete Grid Code Compliance testing, following which Operational Certificates[5] are issued.

Table 5: Customers Certified Operational in 2018

	Total number of sites certified operational 2018	Total new capacity of sites certified operational 2018
New WFPS	6	182 MW
New Conventional	0	0 MW
Reissued Op Certs	WFPS: 9 DSU: 34	WFPS: 199 MW DSU: 38 MW

4.2.5 Maintenance Works Completed

Transmission maintenance is undertaken in accordance with EirGrid's maintenance policy to ensure that the transmission system can operate in a safe, secure and reliable manner. The policy comprises continuous and cyclical condition monitoring (on-line and off-line), preventative maintenance of plant and the implementation of corrective maintenance tasks. The maintenance policy is kept under review to ensure that it continues to meet the requirements of the system and best international practice[6]. On an annual basis, transmission maintenance activities dictated by the asset maintenance policy and protection maintenance policy, along with work identified from analysis of plant condition and work carried over from the previous year combine to form the planned maintenance requirements for the year. This is then included in the Transmission Outage Plan.

During the relevant year, due to a variety of reasons (including resource limitations, outage restrictions, material availability, system conditions, Capital projects etc.), it may be necessary to defer programmed maintenance activities. We will consider the appropriateness or otherwise of deferring preventive and/or corrective maintenance activities. This is subject to prioritisation and deferral assessments in accordance with established EirGrid procedures. These assessments will consider system/safety/environmental impact, duration of outage, controls and mitigation measures.

[5] EirGrid issues Operational Certificate Justifications for distribution WFPS. These are the included in the figures shown.

[6] www.eirgridgroup.com/site-files/library/EirGrid/Guide-to-Transmission-Equipment-Maintenance- March-2018.pdf

Deferrals are kept under review, as any increase in backlog could have a negative impact on the reliability and performance of the transmission system.

Table 6 provides, in volume terms, a summary of transmission maintenance requirements, maintenance programmed and maintenance completed in 2018 for overhead lines, underground cables and transmission stations.

Table 6: Maintenance Summary for 2018

Volume of Transmission Maintenance by Activity	**Maintenance Programme Year End**	**Maintenance Completed**
Overhead Line Maintenance		
Patrols (incl. Helicopter, climbing, infrared & Bolt) [km]	9,765	9,765
Timber Cutting [km]	97.7	85.5
Structure & Hardware Replacement [Number]	162	123
Insulator & Hardware Replacement [Number]	43	40
Underground Cable Maintenance		
Alarms / Cable Inspection [Number]	325	217
Station Maintenance		
Ordinary Service [Number]	294	211
Operational Tests [Number]	773	553
Condition Assessment of Switchgear [Number]	127	96
Tap Changer Inspection [Number]	4	3
Corrective Maintenance Tasks [No. of Tasks]	533	303

4.3 General System Performance

4.3.1 Under-Frequency Load Shedding

There were no UFLS disturbances in 2018 which resulted in shedding of normal tariff load customers.

The relays to disconnect normal tariff customer load are only activated once the system frequency drops to 48.85 Hz. The lowest system frequency in 2018 was 49.407 Hz.

Figure 4 provides a trend of the number of disturbances since 2004 that involved operation of under-frequency relays to disconnect interruptible and normal tariff end-users. No normal tariff customers have been disconnected due to an under-frequency disturbance since 2014.

The short term active response (STAR) interruptible load scheme was discontinued in April 2018.

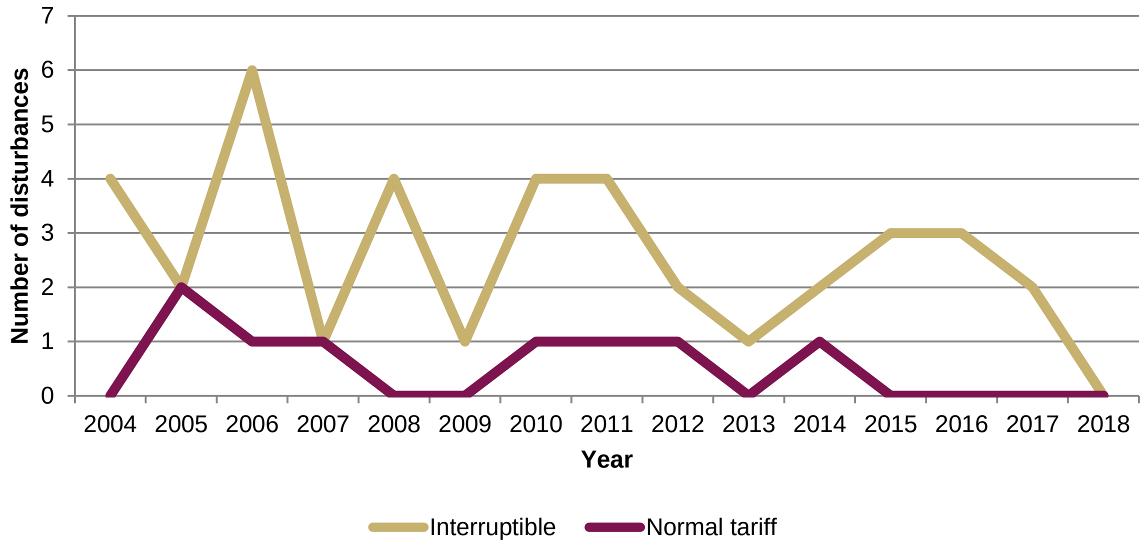

Figure 4: Under frequency disturbances 2004-2018

Figure 5 provides a trend of the lowest system frequency by year since 2004.

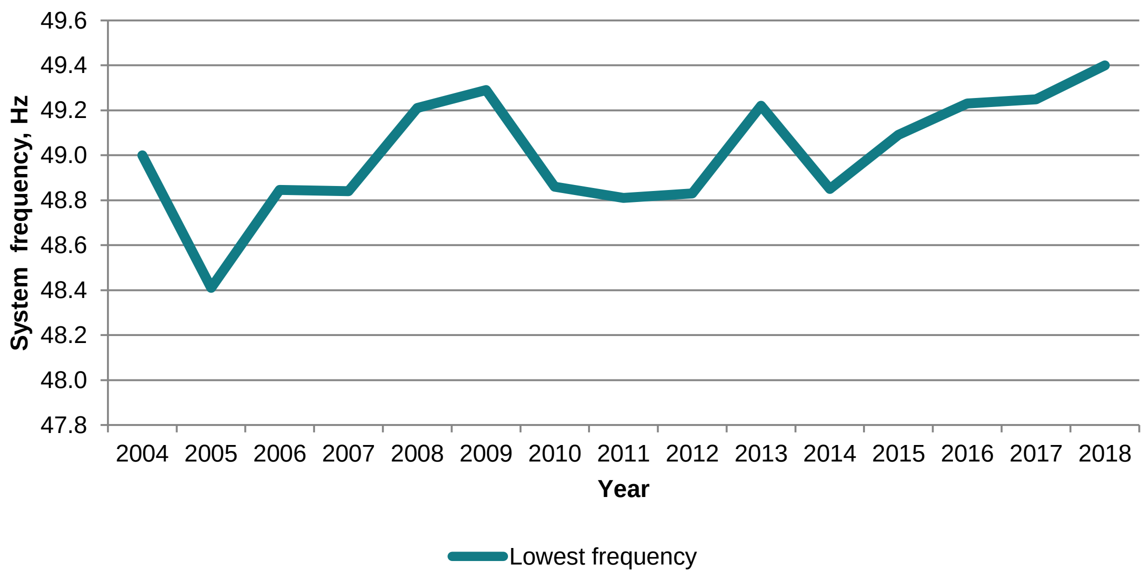

Figure 5: Lowest system frequency 2004-2018

4.3.2 Under-Voltage Load Shedding

There was no incident of Under-Voltage Load Shedding in 2018.

4.4 System Minutes Lost

This section provides information for system minutes lost (SML) attributable to the transmission system operator.

System minutes lost is a measure of the energy not supplied for a disturbance. The metric takes account of the load lost (MW), duration of disconnection (minutes) and peak system demand (MW), to allow for historical comparison. For example, if 300 MW were lost for 10 minutes and the system peak was 3000 MW, this would represent one system minute.

- System minutes = (load x duration) / (system peak) = (300 x 10) / 3000 = 1

The total system minutes lost (SML) as a result of faults on the main system for 2018, attributable to EirGrid, was 0.411. There were no under-frequency load shedding disturbances which resulted in the disconnection of normal tariff load customers.

The trend of system minutes lost since 2004 is shown in Figure 6, with incentive/penalty limits and deadbands as provided by the Commission for Regulation of Utilities (CRU). The central target provided until 2010 was replaced in 2011 with a deadband between 1.5 and 3.0 SML, where there is neither penalty nor incentive. One fifth of the incentive amount is awarded for every 0.1 SML below 1.5 SML, down to 1.0 SML. One fifth of the incentive amount is penalised for every 0.1 SML above 3.0 SML, up to 3.5 SML.

The mean number of system minutes lost per year since 2004 was 1.109.

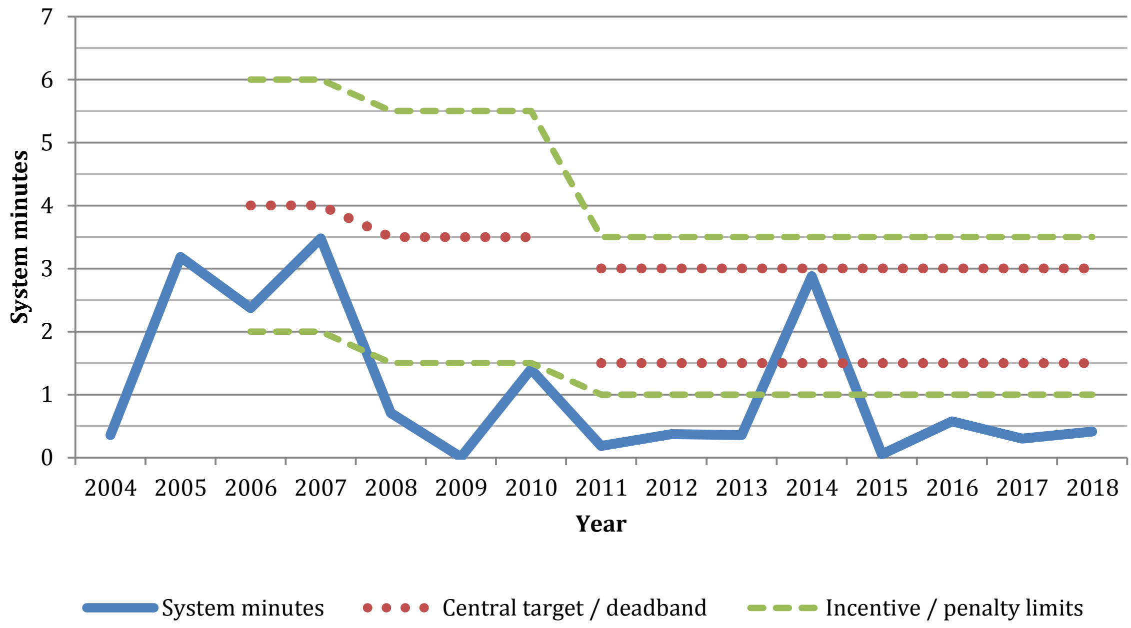

Figure 6: System minutes lost and associated targets: EirGrid 2004-2018

4.5 Zone Clearance Ratio

This section provides details of the short circuit faults on the main system and outside the main system for which main system protection is expected to operate without delay.

Zone clearance ratio (ZCR) is defined as the ratio of the number of short circuit faults, not cleared in zone 1 to the total number of short circuit faults per year cleared by main system protection. See Appendix A for further definition of Zones and ZCR.

Of the 48 short circuit faults in 2018, main system protection was expected to operate without delay for 42 faults. Three of those 42 faults had non-zone 1 clearances, giving a zone clearance ratio of 0.071. The ZCR trend since 2004 is shown in Figure 7.

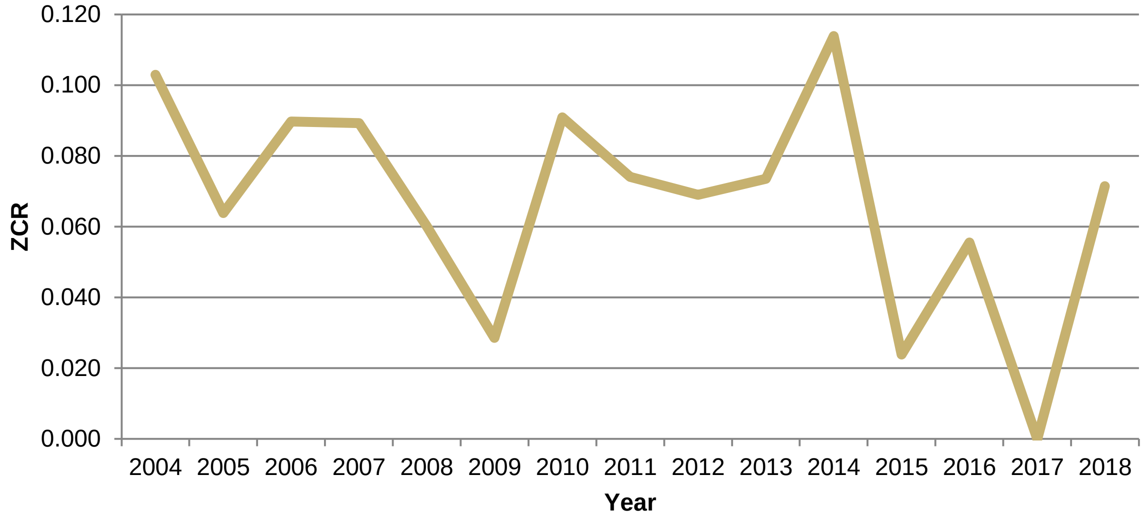

Figure 7: Zone clearance ratio: EirGrid 2004-2018

There were 86 system faults cleared by protection on the main system. This figure is made up of 56 faults on the main system and 30 faults outside the main system.

4.5.1 Frequency Control

In 2018 the system frequency was operated between 49.9 Hz to 50.1 Hz for 99.65% of the time.

4.6 Summary of key disturbances

4.6.1 Loss of load

In April, the Grange Castle-Griffinrath-Maynooth 110 kV line tripped to clear a three-phase fault caused by operation of a disconnect under load in Griffinrath. There was a loss of 0.357 system minutes.

In June, the A3 and B3 110 kV busbars in Ardnacrusha were inadvertently isolated from the system. There was an interruption to end-users supplied from T141 in Ardnacrusha, resulting in the loss of 0.054 system minutes.

In July, the Dallow-Portlaoise-Shannonbridge 110 kV line tripped and reclosed to clear a single phase to ground fault (RE) caused by vegetation. There was a brief interruption to end-users supplied from T141 in Dallow, resulting in the loss of 0.000095 system minutes.

4.6.2 Under-Frequency Load Shedding

There were no under frequency load shedding disturbances in 2018.

4.6.3 Storms

Between 17:35 hours on 02 January and 03:05 hours on 03 January, there were ten faults across the west during Storm Eleanor. The faults were caused by wind and lightning.

There were eight single-phase to ground faults on overhead lines; one at 220 kV, six at 110 kV, and one on a 110 kV distribution line. There were seven zone 1 and one zone 2 clearances. Fault clearance times were between 65 ms and 405 ms.

The Moy-Tawnaghmore 1 110 kV line and 100CAP2 in Castlebar tripped in sympathy with a single phase to ground fault (TE) on the Castlebar-Cloon 110 kV line.

There were no supply interruptions as a result of the disturbance.

4.7 Transmission System Availability & Outages

4.7.1 Transmission System Availability

When considering transmission system availability, it is the convention to analyse it in terms of transmission system unavailability. The formula for calculating transmission system unavailability is given in Appendix 1. Figure 8 shows the percentage Transmission System Unavailability in each month for 2018.

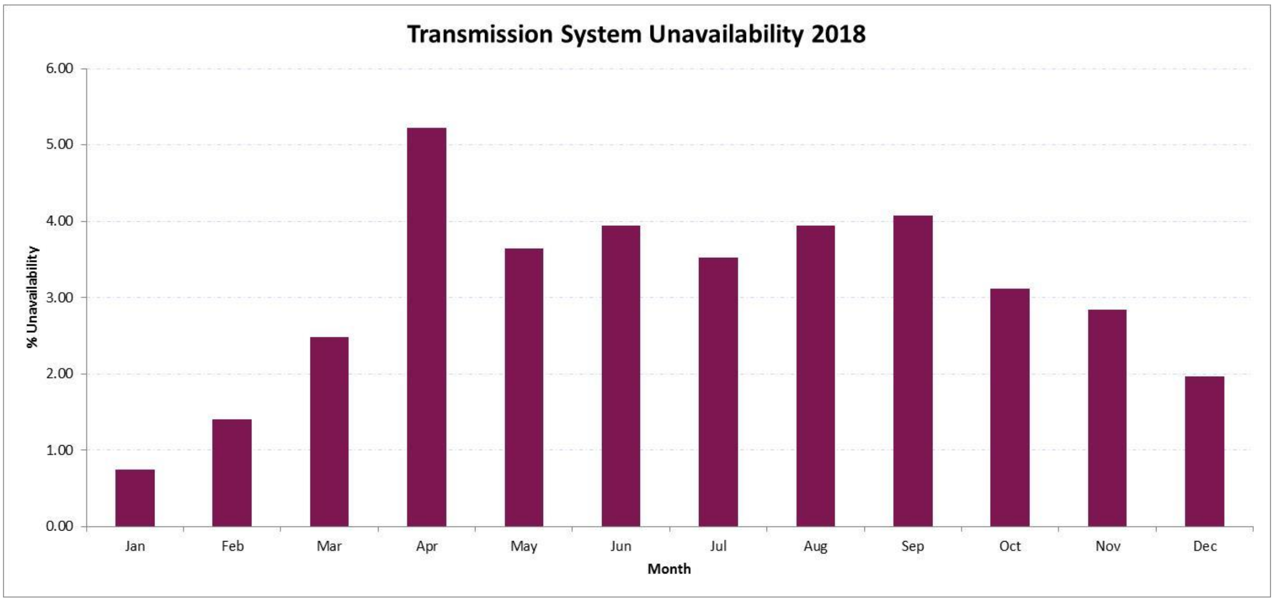

Figure 8: Monthly Variations of System Unavailability 2018

4.7.2 Transmission Plant Availability

The measure of plant availability is the kilometre-day for feeders and the MVA-day for transformers. The availability figures vary between the different categories of plant. The formulae for calculating transmission plant availability are provided in Appendix 1.

Table 7 provides a detailed breakdown of all plant availability figures for 2018.

Table 7: Transmission System Plant Availability 2018

Plant Type	Circuit Length [km]	Number of Outages	Availability (%) 2018
110 kV Circuits	4,345	467	97.23
220 kV Circuits	1,934	111	97.92
275 kV Circuits	97	2	97.45
400 kV Circuits	439	9	89.69
Plant Type	**Transformer Capacity [MVA]**	**Number of Outages**	**Availability (%) 2018**
220 / 110 kV Transformers	10,739	151	94.88
275 / 220 kV Transformers	1,200	8	97.98
400 / 220 kV Transformers	4,050	37	93.59
Total	6,814 km 15,989 MVA	785	95.53

In 2018:

- The average transmission system plant availability was 95.53%;
- The maximum availability by plant type was 97.98%, which occurred on the 275/220 kV transformers; and
- The minimum availability by plant type was 89.69%, which occurred on the 400 kV circuits.

4.7.3 Cause of Transmission Plant Unavailability

Transmission plant unavailability is classified into the categories outlined in Table 8.

Table 8: Transmission System Plant Unavailability Categories

Category	Description
Forced & Fault	Refers to unplanned outages. An item of plant trips or is urgently removed from service. Usually caused by imminent plant failure. There are three types of forced outage: A) Fault & Reclose B) Fault & Forced C) Forced (No Tripping) The above forced outages are explained in detail in Section 6.6.
Safety & System Security	**Safety:** Refers to transmission plant outages which are necessary to allow for the safe operation of work to be carried out. **System Security:** Refers to outages which are necessary to avoid the possibility of cascade tripping or voltage collapse as a result of a single contingency. When a line is out for maintenance it may be necessary to take out additional lines for this reason.
New Works	An outage to install new equipment or uprate existing circuits.
Corrective & Preventative Maintenance	**Corrective Maintenance:** Is carried out to repair damaged plant. Repairs are not as urgent as in the case of a forced outage. **Preventative Maintenance:** Is carried out in order to prevent equipment degradation which could lead to plant being forced out over time. Includes line inspections, tests and routine replacements.
Other Reasons	A number of other reasons may be attributed to plant unavailability, such as testing, protection testing and third party work.

4.7.4 110 kV Plant Unavailability

Figure 9 provides a breakdown of the causes of unavailability on the 110 kV network in 2018.

The largest contributor to unavailability (53%) on the 110 kV network in 2018 were outages for the purpose of corrective and preventative maintenance. This type of maintenance includes, amongst others, ordinary services, condition assessments, wood-pole replacement/straightening and general line maintenance. The most significant of these, was the outage of the Castlebar-Dalton110 kV Line, which lasted 56 days. This was to facilitate the uprating of the Dalton bay and to carry out maintenance works.

A further 25% of unavailability on the 110 kV network was attributable to the "New Works" category. This category is for outages to install new equipment or uprate existing circuits. The most significant of these was the outage of the Binbane-Letterkenny 110 kV line. The purpose of this outage was to install a new sectionalising circuit breaker between sections of busbar and relocate the Trillick bay.

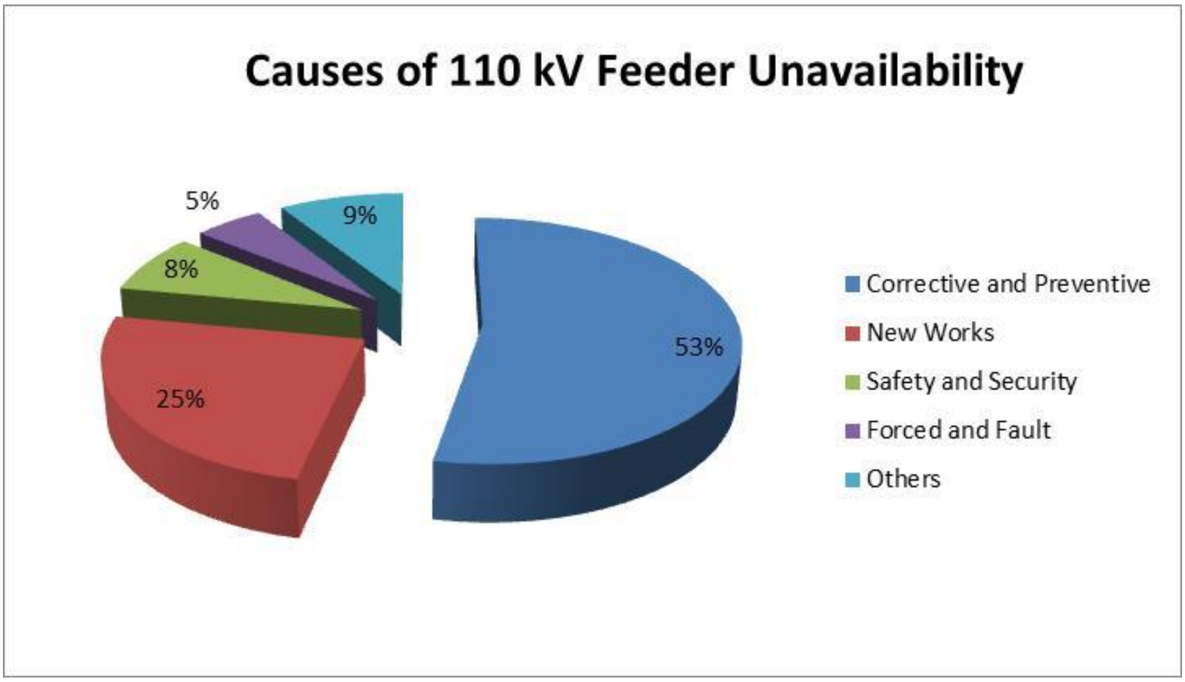

Figure 9: Causes of Unavailability on the 110kV System in 2018

4.7.5 220 kV Plant Unavailability

Figure 10 provides a breakdown of the causes of unavailability on the 220 kV network in 2018.

The largest contributor to unavailability (61%) on the 220 kV network in 2018 were outages for the purpose of corrective and preventative maintenance. The most significant of these was the outage of the Killonan-Shannonbridge 220 kV circuit for 14 days. The purpose of this was to repair voltage transformer fuses at Shannonbridge.

Approximately 7% of unavailability on the 220 kV network was attributable to Forced and Fault. The most significant of these outages was on the Glanagow-Raffeen 220 kV circuit which lasted 58 days. The purpose of this was to repair a subsea cable fault.

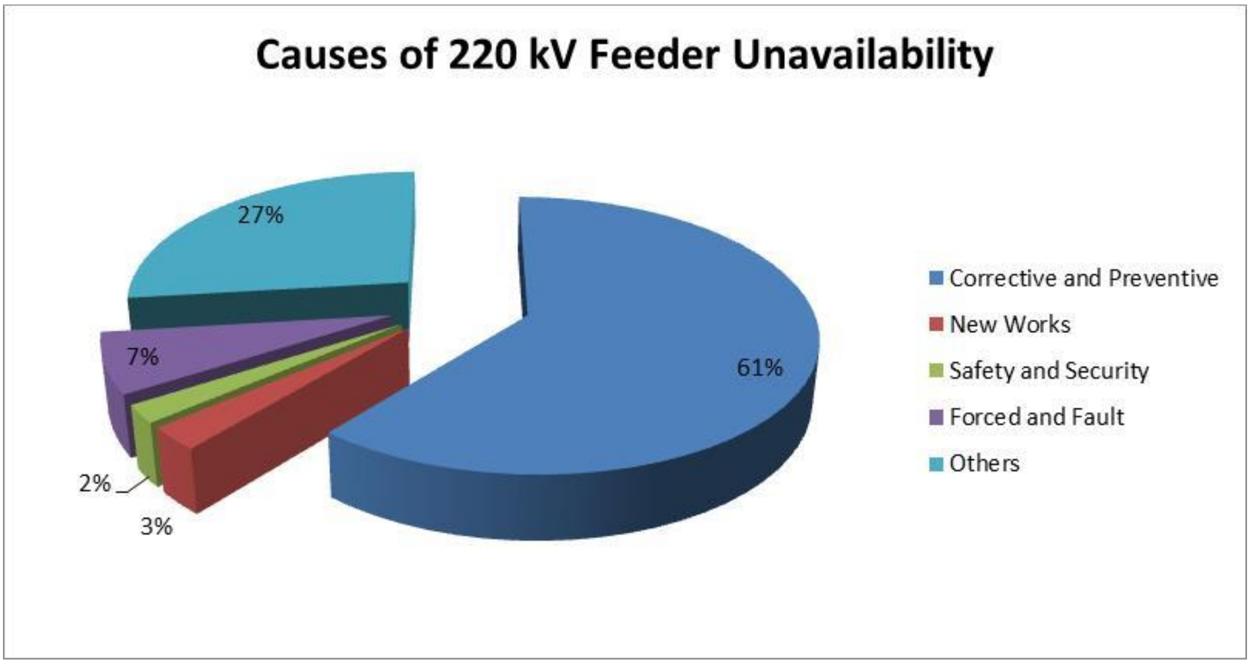

Figure 10: Causes of Unavailability on the 220kV System in 2018

4.7.6 275 kV Plant Unavailability

The 275 kV tie-line consists of 48.5 km of 275 kV double-circuit between Louth station and Tandragee station which is situated in County Armagh. In 2018 there were 2 outages of 275 kV tie-lines, with both Louth-Tandragee 1 (ONE) and Louth-Tandragee 2 (TWO) on outage for 9 days.

4.7.7 400 kV Plant Unavailability

Figure 11 provides a breakdown of the causes of unavailability on the 400 kV network in 2018.

The largest contributor to unavailability (74%) on the 400 kV network in 2018 was new works. The most significant of these was the outage of the Moneypoint-Oldstreet 400 kV line. This 117 day outage was to facilitate the transfer of the Oldstreet 400 kV circuit to the Moneypoint New 400 kV GIS Station.

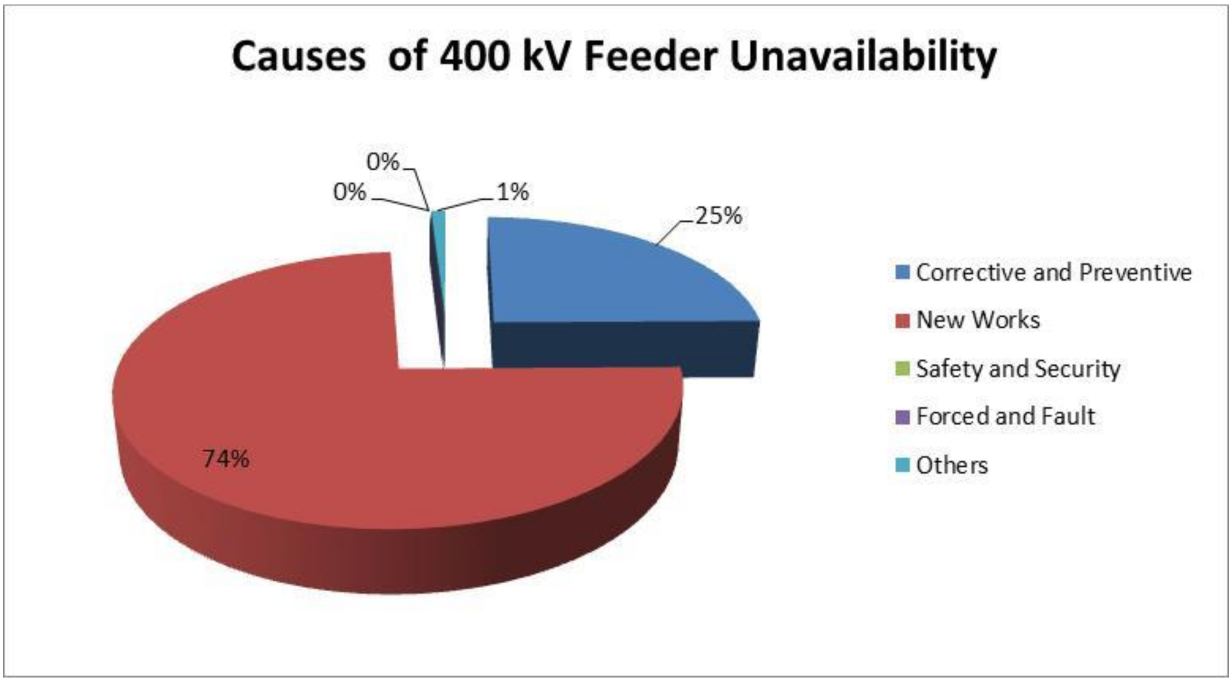

Figure 11: Causes of Unavailability on the 400kV System in 2018

Table 9 provides a breakdown of the transmission system outages that occurred in 2018 by plant type.

Table 9: Transmission System Plant Outage 2018

Plant Type	No. of Items	Circuit Length	Forced & Fault	Safety & System Security	New Works	Corrective & Preventive Maintenance	Other	Total No. of Outages
110 kV Circuits	467	4,345	29	16	72	310	40	467
220 kV Circuits	111	1,934	8	5	15	67	16	111
275 kV Circuits	2	97	0	0	0	0	2	2
400 kV Circuits	9	439	0	0	4	2	3	9
Total	589	6,814	37	21	91	379	61	589
Plant Type	**No. of Items**	**Transformer Capacity**	**Forced & Fault**	**Safety & System Security**	**New Works**	**Corrective & Preventive Maintenance**	**Other**	**Total No. of Outages**
220 / 110 kV Trafos	54	10,739	17	3	21	93	17	151
275 / 220 kV Trafos	3	1,200	1	0	0	0	7	8
400 / 220 kV Trafos	8	4,050	9	1	5	11	11	37
Total	65	15,989	27	4	26	104	35	196

4.7.8. East West Interconnector

The East West Interconnector (EWIC) is a high-voltage direct current (HVDC) scheme which links the power systems of Ireland and Great Britain. It has a power rating of 500 MW. EWIC is a fully regulated interconnector which was developed and is owned by EirGrid Interconnector DAC (EIDAC) which is part of the EirGrid Group. The scheme consists of two Converter Stations located in Meath, Ireland and Deeside, Wales connected by 264 km HV cable, 185 km of which is submarine.

4.7.9. East West Interconnector Unavailability

In 2018 the availability of the East West Interconnector (EWIC) was 87%.

Outages contributing to EWIC unavailability included maintenance works, forced outages and black start testing in Portan Converter Station.

4.7.10 Transmission Outage Duration

The duration of transmission outages is useful for assessing transmission system performance. Transmission outages are broken into eight time classifications ranging from less than 10 minutes to greater than four weeks. The total number of outages in each time classification is shown in Figure 12.

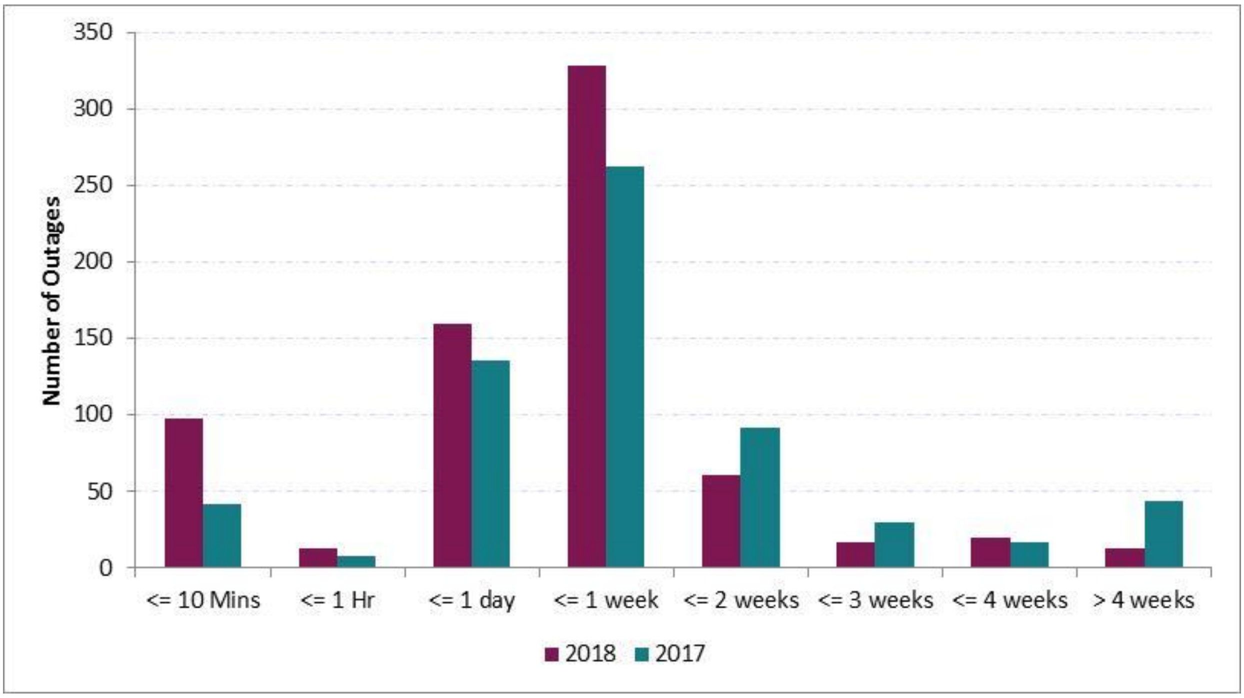

Figure 12: Duration of Outages in 2017 & 2018

The two most frequent transmission system outage periods occur between one hour and one day and between one day and one week. In the category of one hour to one day, outages can be arranged to avoid peak load times and thereby reduce the impact on the system, while one week outages for annual maintenance are commonplace during the outage season.

4.7.11 Timing of Transmission Outages

Transmission outages are scheduled, where possible, during periods of low load in the summertime (however, this can be limited by a number of factors such as personnel availability and shortage of hydro-power support in some areas). The seasonal nature of transmission outages is apparent in Figure 13 below.

Figure 13 shows the percentage unavailability of the transmission system in each month. The March-November period (known as the outage season) sees the highest rates of unavailability during the year, when decreased system load is taken advantage of to carry out extensive maintenance outages such as the 26 day outage of Cushaling-Newbridge 110 kV circuit to carry out Corrective and Preventative Maintenance. Figure 14 shows the average duration in days of the transmission outages in each month in 2018.

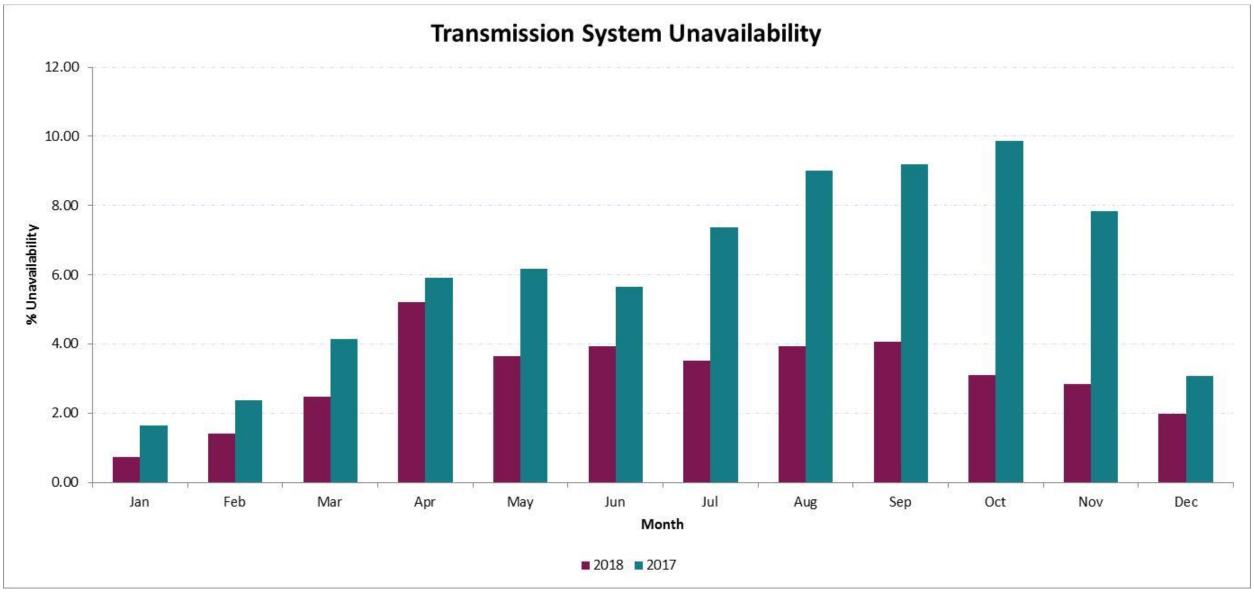

Figure 13: Percentage unavailability in each month of 2017 & 2018

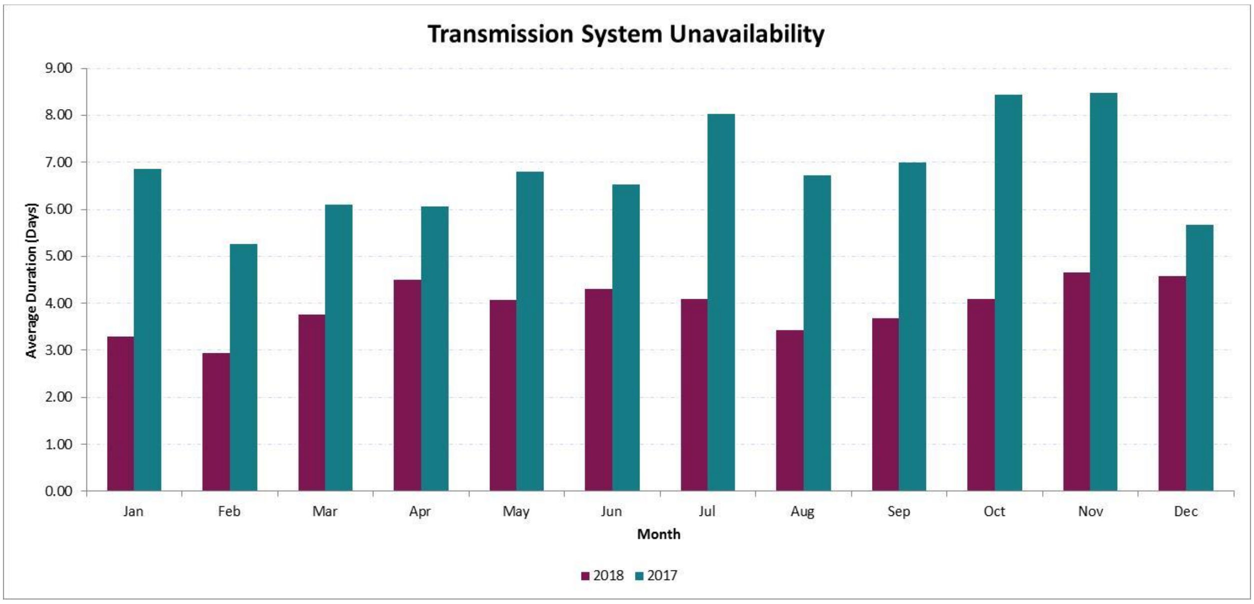

Figure 14: Average duration of outages 2017 & 2018

4.7.12 Forced Outages

There are two main outage classifications, voluntary outages and forced outages. The majority of outages are voluntary outages that are scheduled by EirGrid. Forced outages are not scheduled and cause the most disruption to the transmission system. Due to their disruptive nature, forced outages merit further analysis.

4.7.13 Forced Outages per km

The measure used for analysing the forced outages of lines and cables is the number of forced outages per kilometre of feeder, and is shown in Figure 15.

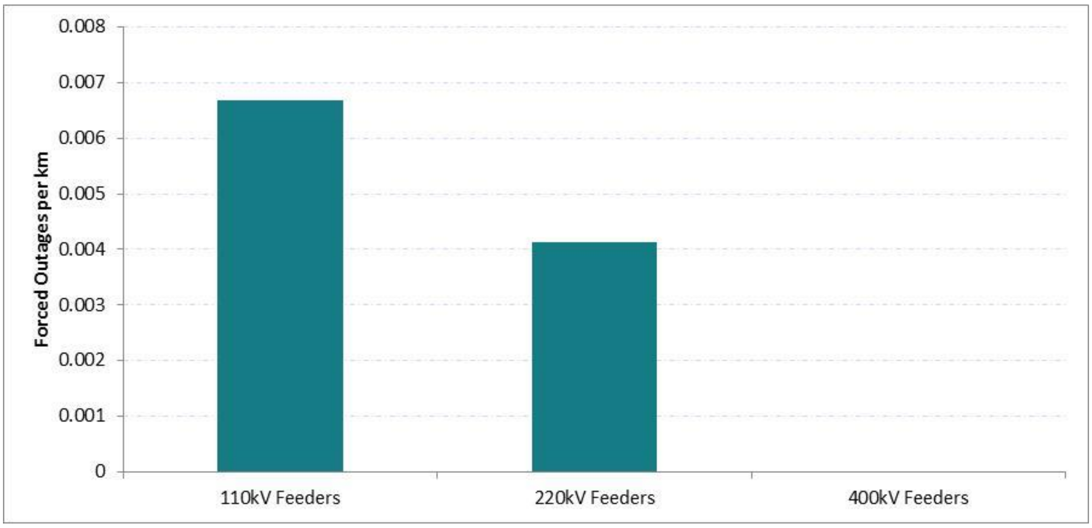

Figure 15: Forced Outages of lines and cables in 2018

4.7.14 Forced Outages per MVA

The measure used for analysing the forced outages of transformers is the number of forced outages per MVA capacity, which can be seen in Figure 16.

Figure 16: Transformer Forced Outages in 2018

5. SONI Transmission System Performance

This section details the performance of the transmission system in Northern Ireland, unless explicitly stated otherwise. This data has been prepared by SONI in accordance with Condition 20 of the ‘Licence to participate in the Transmission of Electricity’.

5.1 Summary

SONI is responsible for the safe, secure, efficient and reliable operation of the Northern Ireland transmission network. The transmission network is operated at 275 kV and 110 kV and is made up of approximately 150 circuits covering a total length of approximately 2,130 km. The primary purpose of the transmission system is to transport power from generators and interconnectors to bulk supply points which connect the transmission system to the distribution system.

Availability is a key measure of power system performance. In this report availability refers to the proportion of time a transmission circuit or interconnector was available.

The annual system availability for 2018 was 96.53%. Several capital projects were completed in 2018 including the connection of two new substations at Dromore Main and Drumquin. This was to facilitate the integration of renewable generation onto the system.

The annual availability of the Moyle Interconnector for 2018 was 99.63%. This is the highest availability on the Moyle interconnector since its connection to the system in 2002.

The North-South 275 kV tie line, connecting Louth in Ireland and Tandragee in Northern Ireland, had an availability of 97% in 2018. The annual availability of the Strabane – Letterkenny and Enniskillen – Corraclassy 110 kV tie lines was 93% and 100% respectively in 2018.

The Electricity Safety, Quality and Continuity Regulations (Northern Ireland) 2012 set out the statutory obligations in relation to managing both frequency and voltage for Northern Ireland. Under the regulation SONI are required to report incidents which have caused interruptions to supplies to customers to the transmission asset owner, NIE Networks. Part 8, paragraph 33 of the regulation contains details of the requirements for the reporting of incidents.

In 2018, there was one transmission incident leading to customers being off supply. This was;

- On 12 December at 03:56, an incident at Rosebank substation resulted in the loss of supply to 22448 customers. The system minutes lost (SML) for this event was 0.622.

Quality of service is measured by the number of voltage and frequency excursions which fall outside statutory limits. There were no voltage excursions in 2018 outside the statutory limits.

The nominal frequency of the all-island transmission system is 50 Hz, and is normally controlled within the range of 49.95 Hz and 50.05 Hz. SONI is required to report on system faults where the frequency drops below 49.8 Hz or above 50.2 Hz. In 2018, there were 35 system events where the frequency exceeded these limits.

The reporting of frequency excursions is carried out in accordance with the definitions and principles of the National Fault and Interruption Reporting Scheme (NAFIRS), (Engineering Recommendation G43/2). The effects of national / regional emergencies and disputes are excluded.

5.2 Transmission System Availability

5.2.1 System Availability

Transmission system availability is the proportion of time a transmission circuit was available during the calendar year. A circuit is defined as the overhead line, cable, transformer or any combination of these that connects two busbars together or connects the transmission system to another system. Transmission system availability is reduced when a circuit is taken out of service, either for planned or unplanned purposes.

Planned outages are necessary to facilitate new user connections, network development and maintenance of network assets necessary to deliver acceptable levels of system security and reliability. These are outages planned with at least seven days' notice.

Unplanned outages can be a result of equipment failure or a fault caused by adverse weather etc. These are outages required immediately or planned with less than seven days' notice.

System Availability is calculated using the formula:

$$\text{Sytem Availability } (\%) = \frac{\sum \text{Hours each circuit is available}}{(\text{No. of Circuits}) * (\text{Total No. Hours in Period})}$$

In 2018, the analysis of the transmission system availability data has produced the following results:

- The average availability of the Northern Ireland transmission system was in 2018 was 96.53%; and
- The average winter system availability (for the winter months January, February, November and December 2018) was 97.95%.

Figure 17 below shows the month by month variation in Transmission System Availability in Northern Ireland.

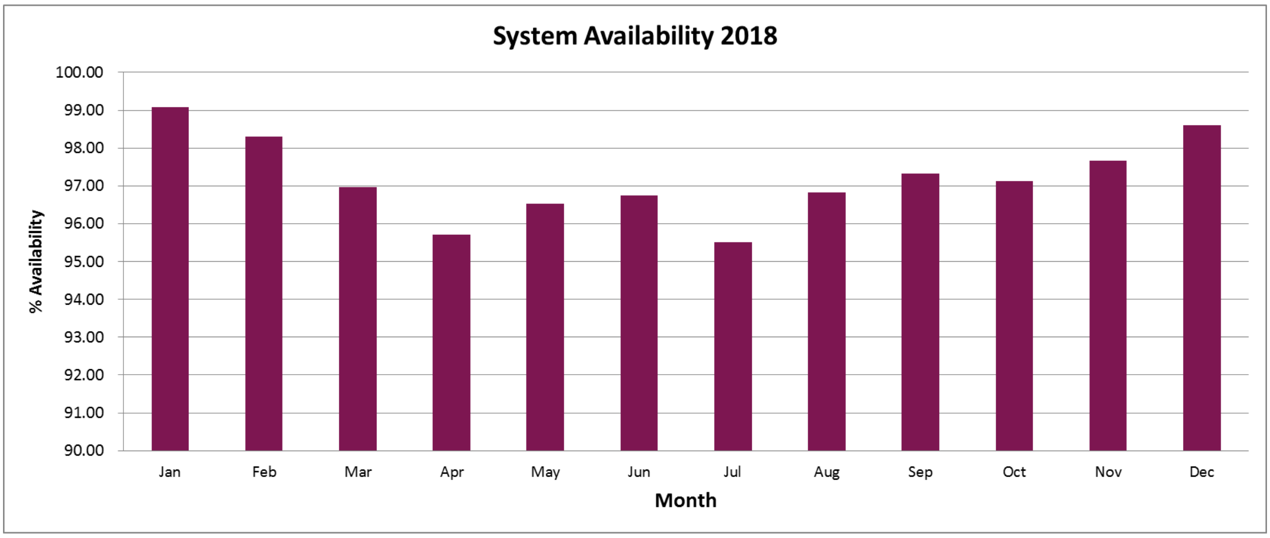

Figure 17: Transmission System Availability 2018

Overall, the availability of the system is high, particularly over the winter months, such as January and December, where maintenance is avoided due to the higher electrical demand and potential adverse weather conditions. The preference is for maintenance to take place over the summer months when network loading is generally lower to mitigate the risk of affecting the supply to customers.

5.2.2 System Unavailability

Figure 18 below shows the month by month variation in planned and unplanned system unavailability.

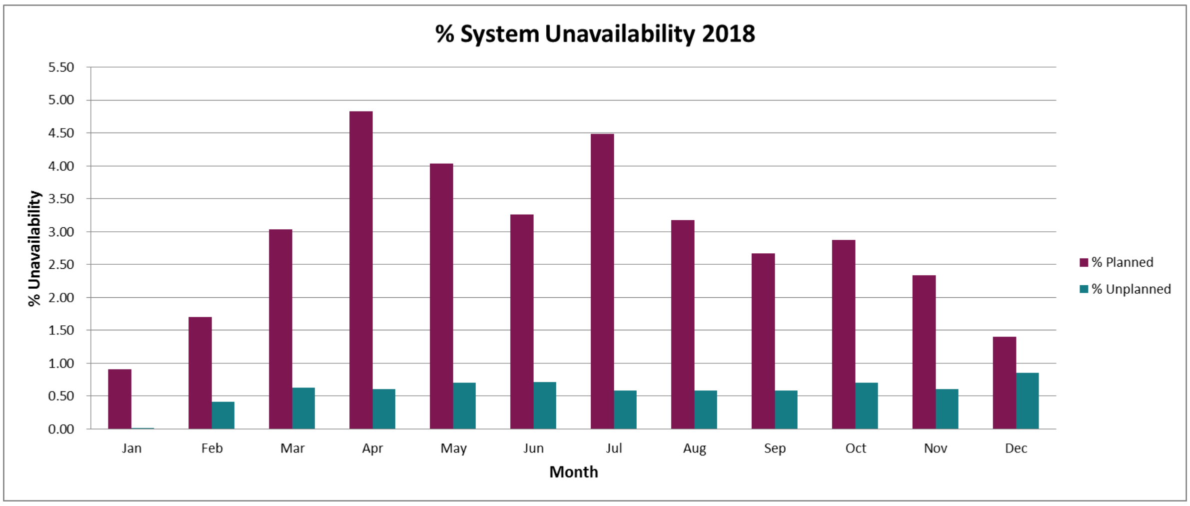

Figure 18: Transmission System Unavailability 2018

The majority of outages occurred during the spring/summer months. This reflects the policy of planning outages during periods of lower electrical demand.

5.2.3 System Historical Availability Performance

Figure 19 shows the historic variation in system availability from 2005/2006 to 2018 for the transmission network in Northern Ireland.

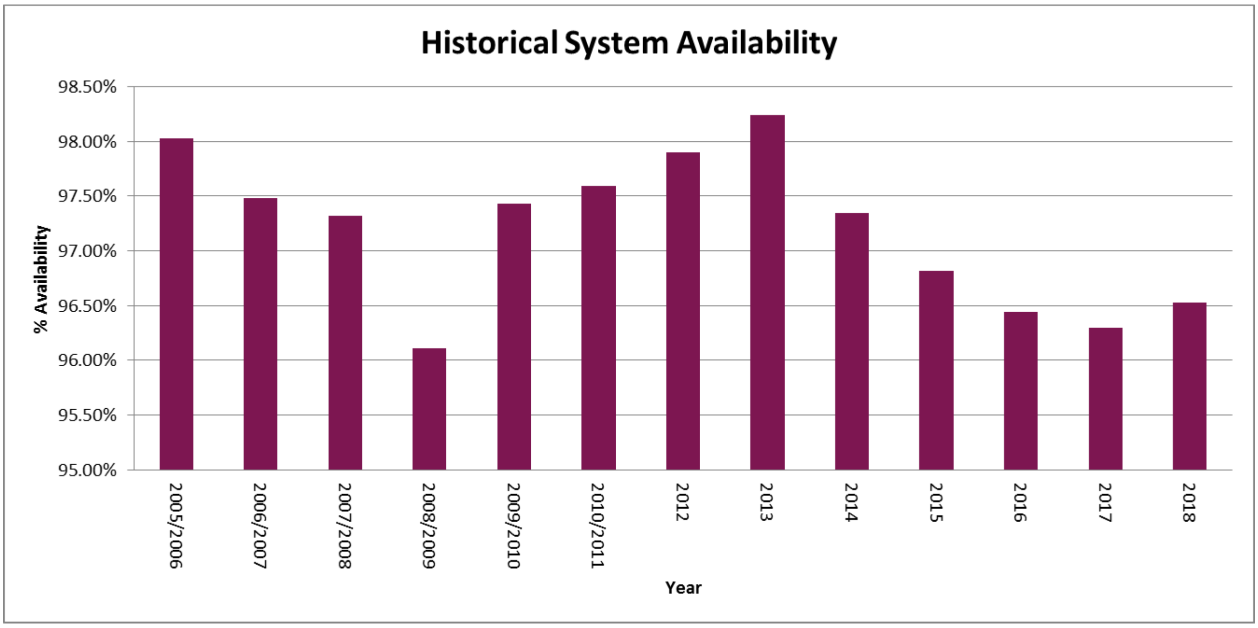

Figure 19: Historical System Availability 2005/2006 to 2018

5.2.4 System Historical Unavailability Performance

Figure 20 below shows the breakdown of the system unavailability from 2005/2006 to 2018.

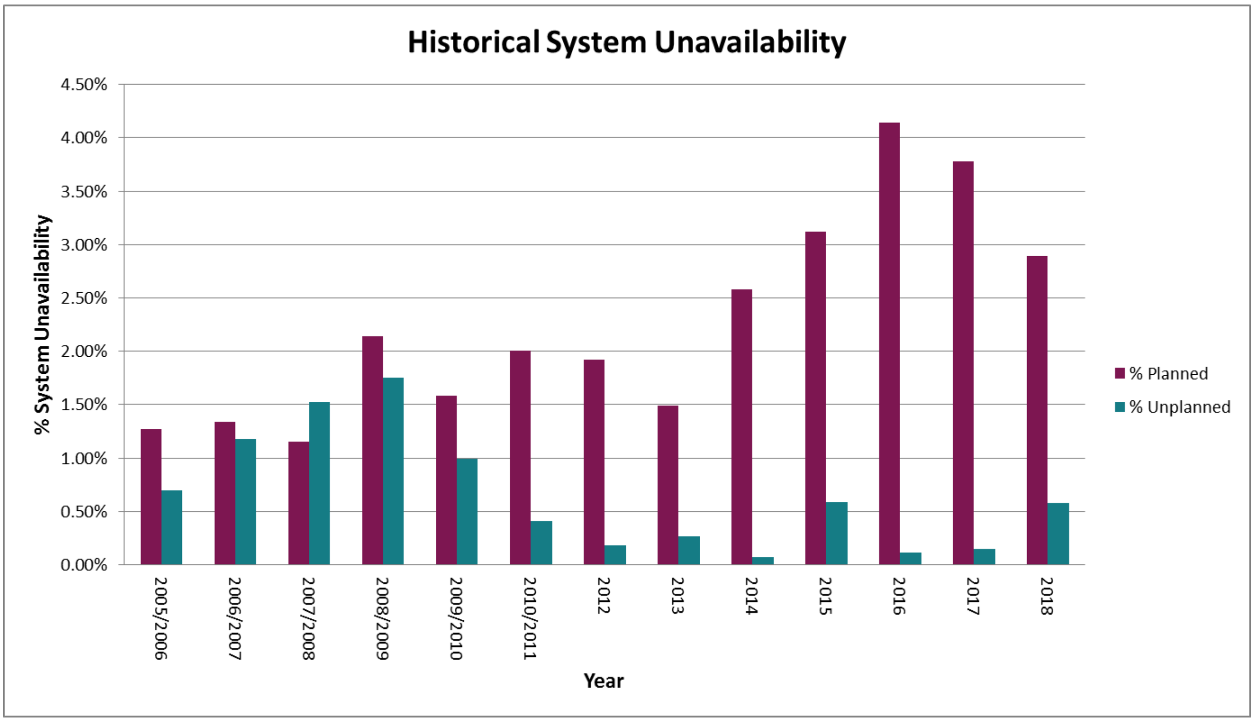

Figure 20: Historical System Unavailability 2005/2006 to 2018

There has been a drop in system unavailability in 2018 compared to 2017, shown in Figure 20 above. In 2018, as part of the price control RP6, NIE Networks has continued its commitment to upgrade existing infrastructure as well as constructing new assets to meet the ongoing needs of the power system. Examples of this include:

- Protection upgrades at 275 kV and 110 kV substations across Northern Ireland;
- New Inter-bus transformers and Current Transformers installed at Castlereagh substation;
- Rosebank reconfiguration; and
- Reconfiguration of Omagh – Enniskillen as a result of the construction of two new substations at Dromore Main and Drumquin. This was to facilitate the integration of further renewables on to the system.

5.2.5 Moyle Interconnector

The Moyle interconnector, owned by Mutual Energy, connects the power systems of Northern Ireland and Scotland. The interconnector is a High Voltage Direct Current (HVDC) system; consisting of two submarine power cables and two HVDC-AC converter stations; one located at Islandmagee in Northern Ireland and the other at Auchencrosh in Scotland. The system has an operational import capacity of 442 MW and an operational export capacity of a maximum 300 MW. Note: Firm export limit on Moyle reduced from 300 MW to 80 MW from 10 November 2017. There is an agreed process between Moyle and NGET on releasing additional "non-firm" export capacity when GB system conditions allow.

The interconnector is operated by SONI, and the performance of the interconnector is detailed in this report.

During 2018, the longest outage taken by Moyle was a two-day scheduled outage in June for maintenance of Pole 2 converter transformers and associated equipment at Ballycronan More Converter Station.

5.2.6 Moyle Interconnector Historical Availability

The Annual Availability of the Moyle Interconnector for 2018 was 99.63%.

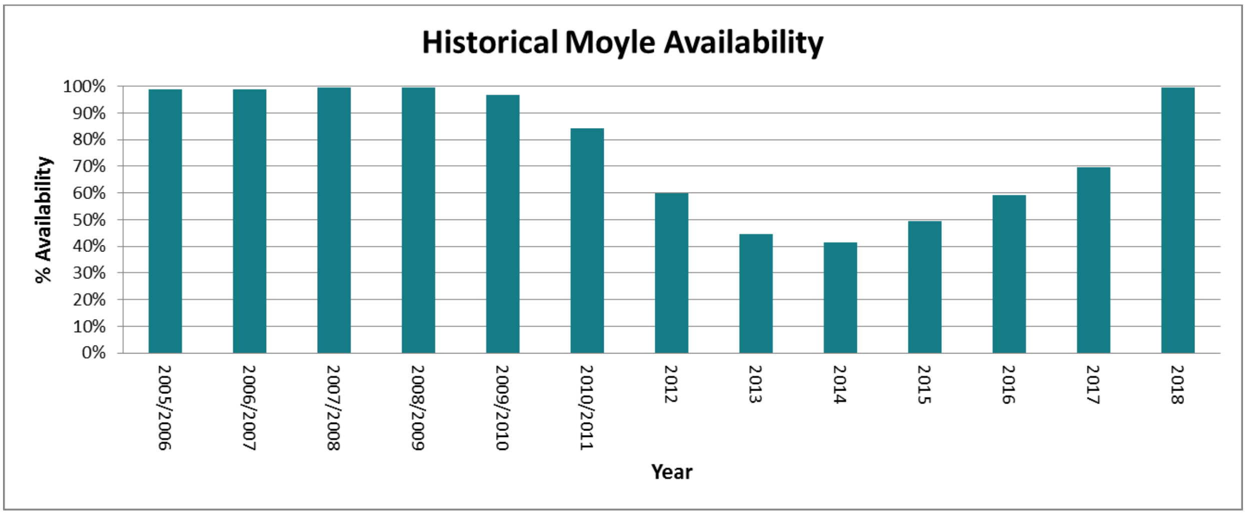

Figure 21: Historical Moyle Interconnector Availability 2005/2006 to 2018

5.2.7 Moyle Interconnector Historical Unavailability

The 2018 Annual Unavailability of the Moyle Interconnector was 0.37%.

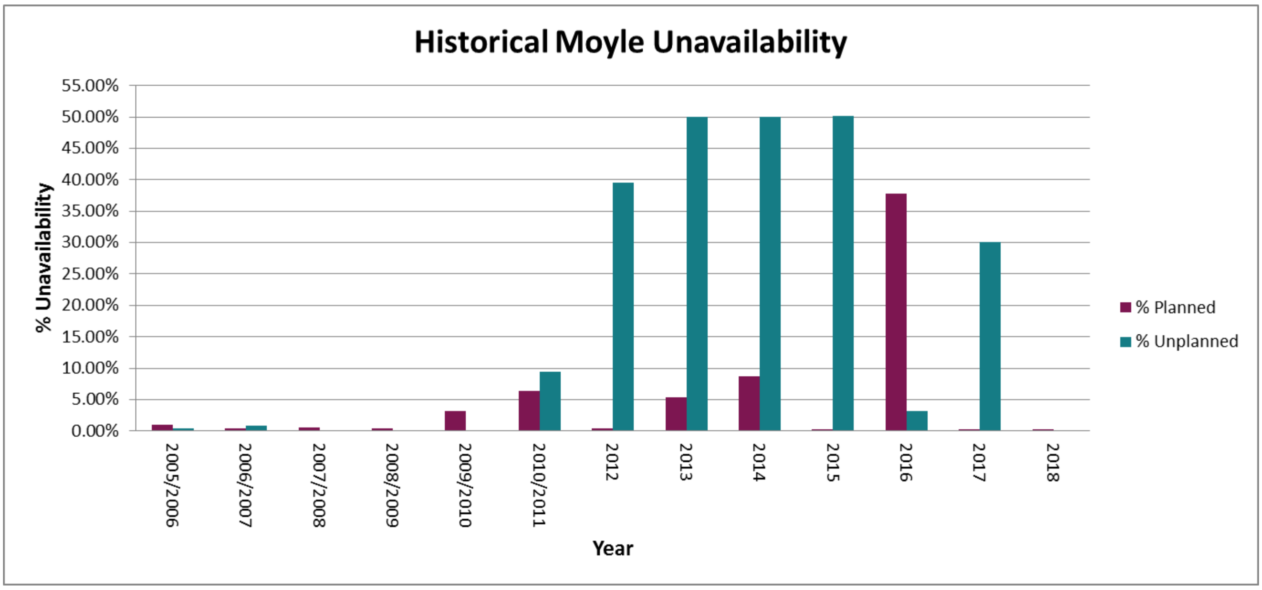

Figure 22: Historical Moyle Interconnector Unavailability 2005/2006 to 2018

5.2.8 Moyle Interconnector Monthly Unavailability

Figure 23 below shows the month by month variation of unavailability of the interconnector.

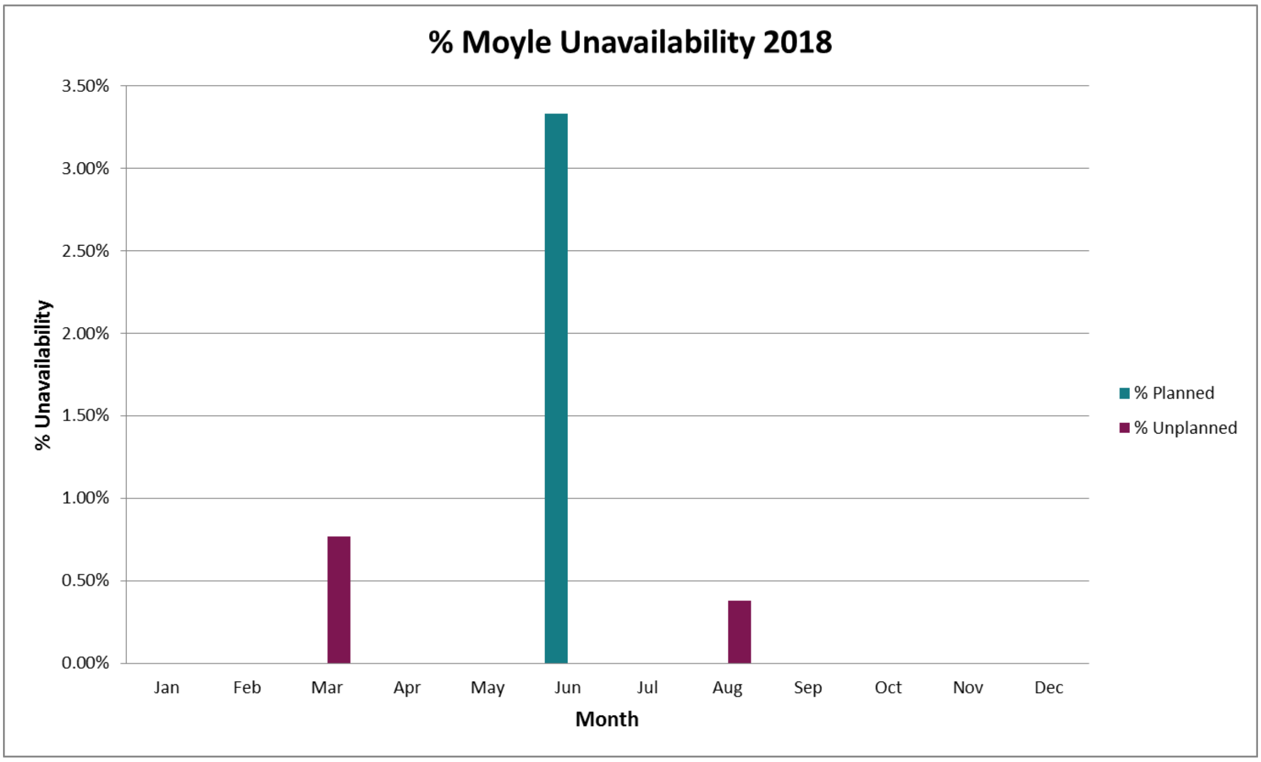

Figure 23: Moyle Interconnector Unavailability 2018

Figure 23 shows the scheduled maintenance that was carried out in June. There were 2 emergency outages in 2018; one in March on Pole 2 and one in August for Pole 1. Both of these emergency outages works were completed within one working day.

5.2.9 275 kV Tie Line

The connections between Ireland and Northern Ireland are referred to as 'Tie Lines'.

The Northern Ireland transmission system is connected to the transmission system in Ireland by means of one 275 kV double-circuit connection from Tandragee 275 kV substation in Co. Armagh to Louth 220 kV substation in Co. Louth.

The 275 kV double-circuit tie line is used as the method for synchronising the Northern Ireland and Ireland power systems together. Energy can flow freely between both jurisdictions, depending on the operating requirements and generating plant being utilised on the all island power system.

The annual average availability of the 275 kV North-South Tie Line in 2018 was 97.42%.

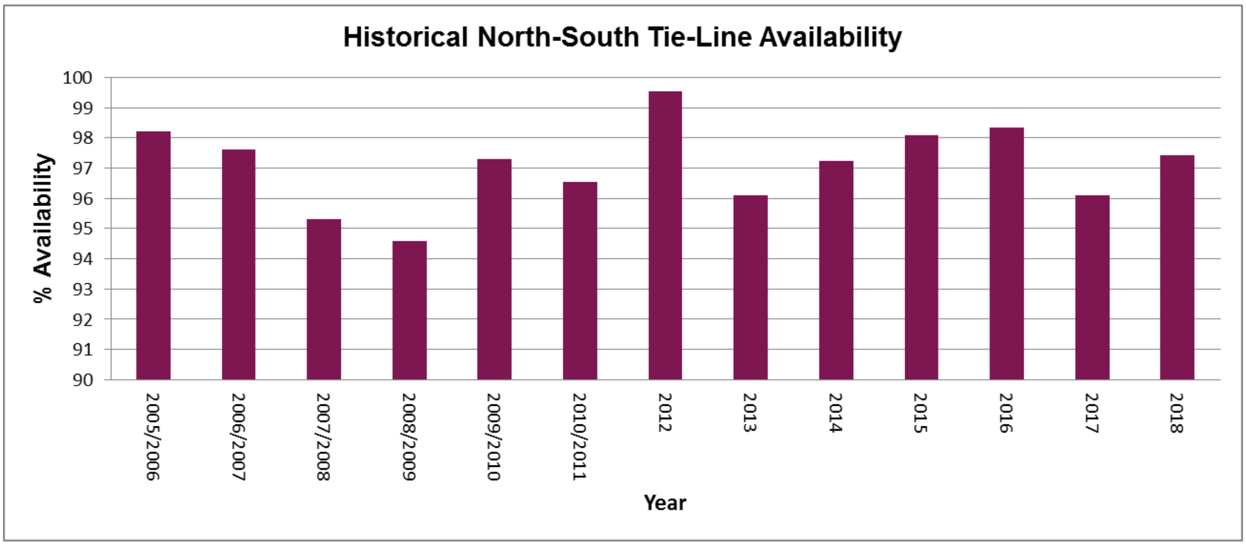

Figure 24: Historical North-South Tie Line Availability 2005/2006 to 2018

5.2.10 110 kV Tie lines

There are two 110 kV connections between Ireland and Northern Ireland:

- Strabane – Letterkenny 110 kV circuit
- Enniskillen – Corraclassy 110 kV circuit

These 110 kV tie lines provide an AC connection between the two transmission systems, which allows emergency flows of active and reactive power for frequency and voltage support, increasing system stability.

Phase Shifting Transformers (PST), designed for energy to flow in two directions, are installed at Strabane and Enniskillen and control the flow of energy between Ireland and Northern Ireland. These PSTs are rated at 125 MW each and are, in normal operation, operated to maintain a 0 MW flow between both jurisdictions. To negate any potential system abnormalities as a result of transmission outages, either scheduled or unplanned, a flow can be manually allowed that can support system operation in both jurisdictions.

Also, in times of high wind, the Strabane-Letterkenny tie line is used to import excess wind energy being produced.

The availability of the 110 kV Tie Lines was 96.61%% in 2018.

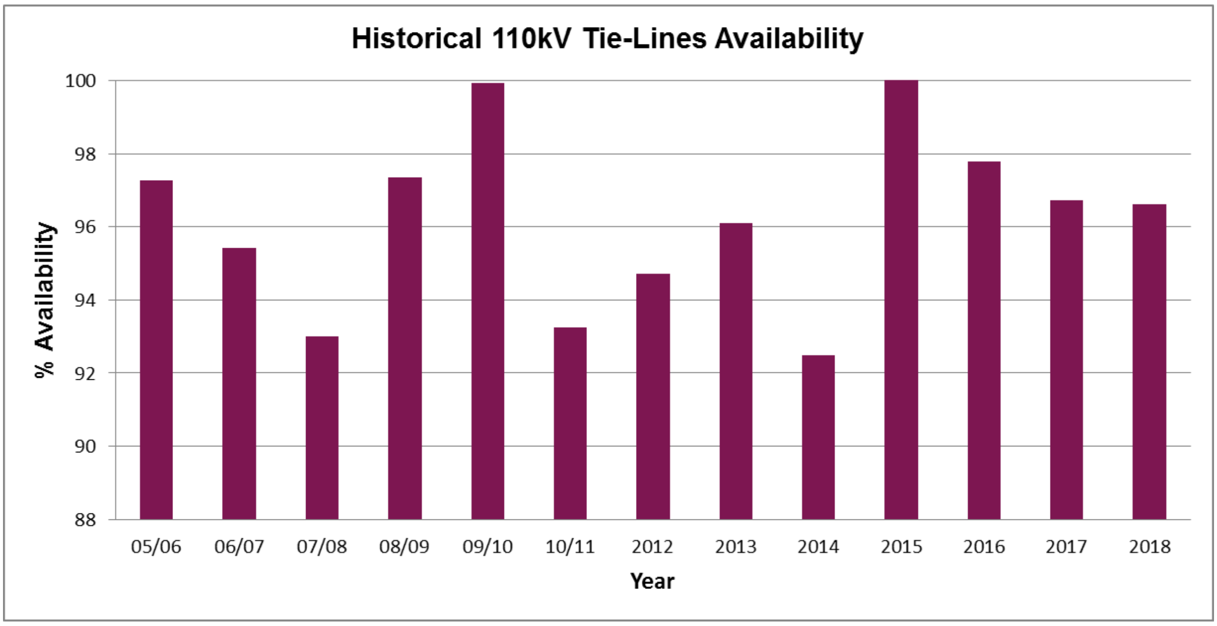

Figure 25: North-South Tie Line Availability 2005/2006 to 2018

A breakdown of 110 kV tie line unavailability is shown in Figure 26 below.

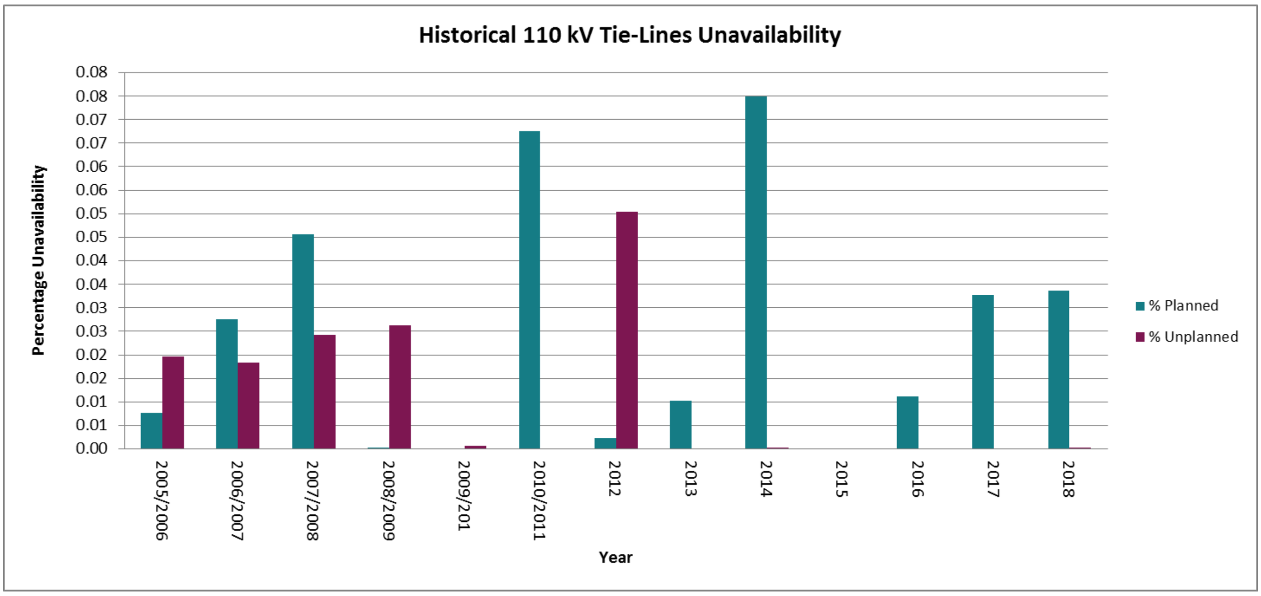

Figure 26: Historical 110kV Tie Line Unavailability 2005/2006 to 2018

5.3 Transmission System Security

An incident is a system event that results in loss of supply. In this section incidents resulting from issues on the Northern Ireland Transmission system are described individually. The following sections detail the nature, location and duration of the incidents with an estimate of energy unsupplied.

5.3.1 Incidents for 2018

The criterion for the reporting of incidents is specified in Part 8, paragraph 33, of 'The Electricity Safety, Quality and Continuity Regulations (Northern Ireland) 2012'. An incident shall be reported if there has been:

- any single interruption of supply, to any demand of 20 megawatts or more at the time of the interruption, for a period of three minutes or longer; or
- any single interruption of supply, to any demand of 5 megawatts or more at the time of the interruption, for a period of one hour or longer; or
- any single interruption of supply to 5,000 or more consumer's installations for a period of one hour or longer.

5.3.2 Number of Incidents and Estimated Unsupplied Energy

In 2018, there was one system event in Northern Ireland that resulted in the loss of supply to customers. Details of this event are given below.

- On the 12th of December at 03:56, an incident at Rosebank substation resulted in the loss of supply to 22,448 customers, equating to a total loss of 17 MW. All customers were fully restored within 114 minutes of the event happening.

5.3.3 Incident Analysis

Figure 27 details the incidents that have occurred historically in Northern Ireland.

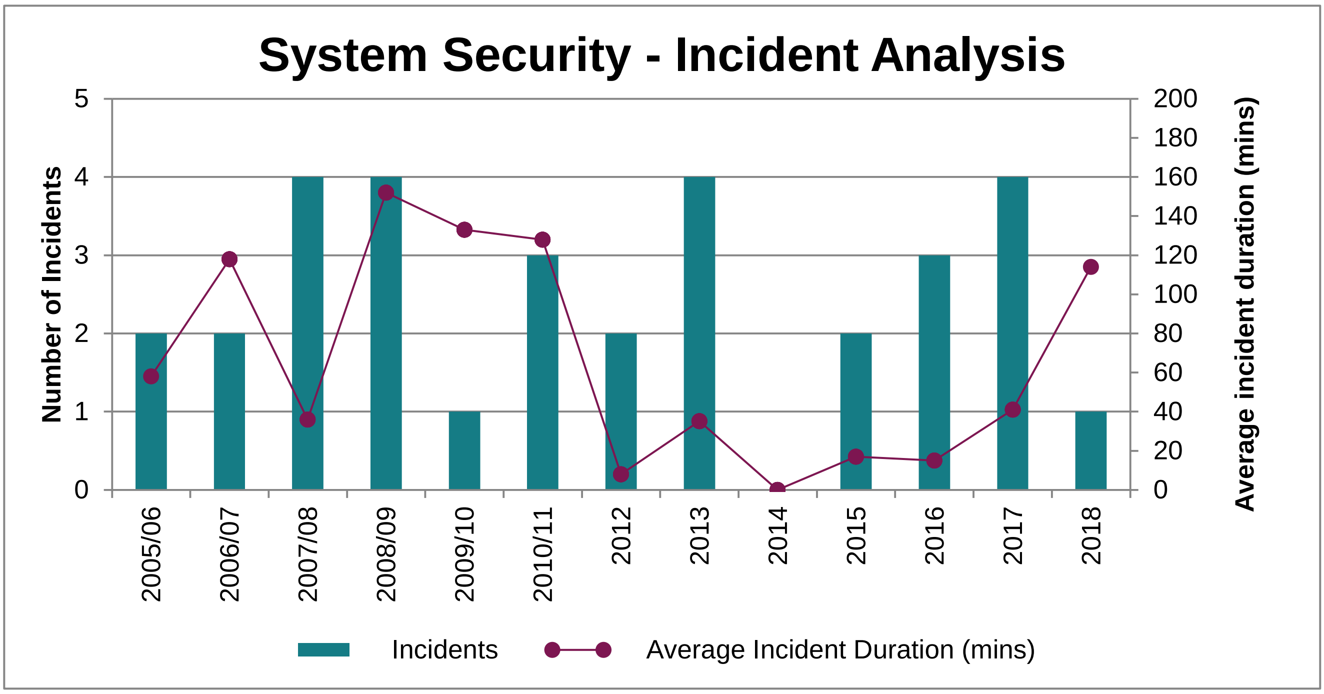

Figure 27: Historical System Security 2005/2006 to 2018

5.3.4 Unsupplied Energy

Figure 28 below shows the historical amount of unsupplied energy to Northern Ireland customers.

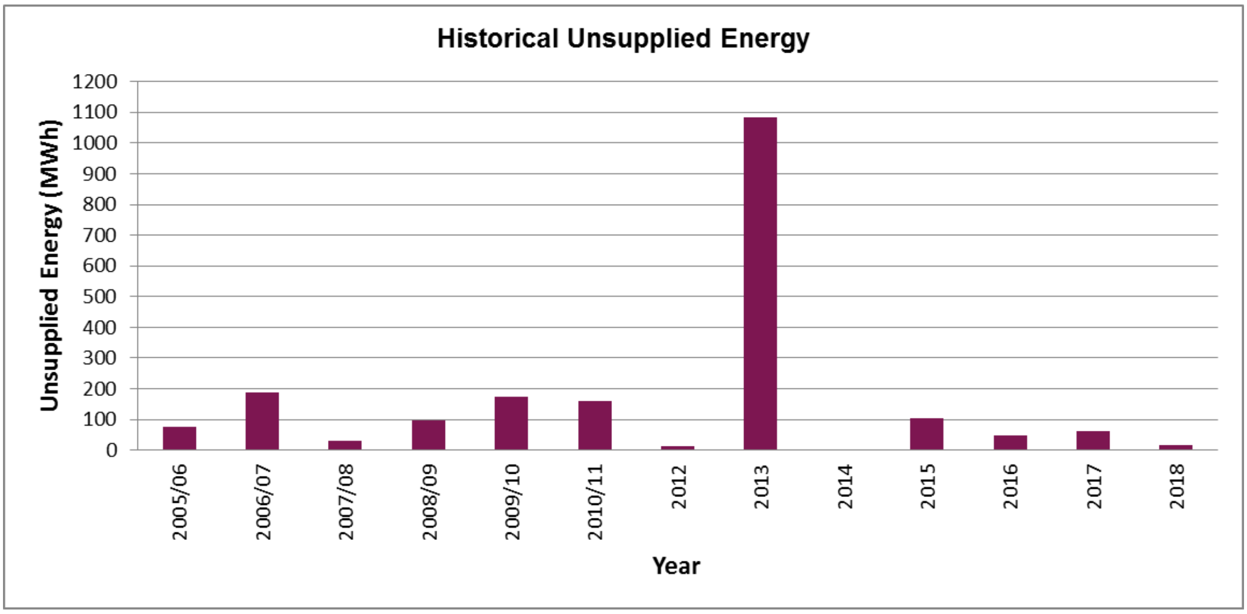

Figure 28: Historical Unsupplied Energy 2005/2006 to 2018

5.3.5 System minutes lost

The total system minutes lost for 2018, attributable to SONI, was 0.622. The trend of system minutes lost since 2012 is shown in Figure 29. The mean number of system minutes lost per year since 2012 was 2.231.

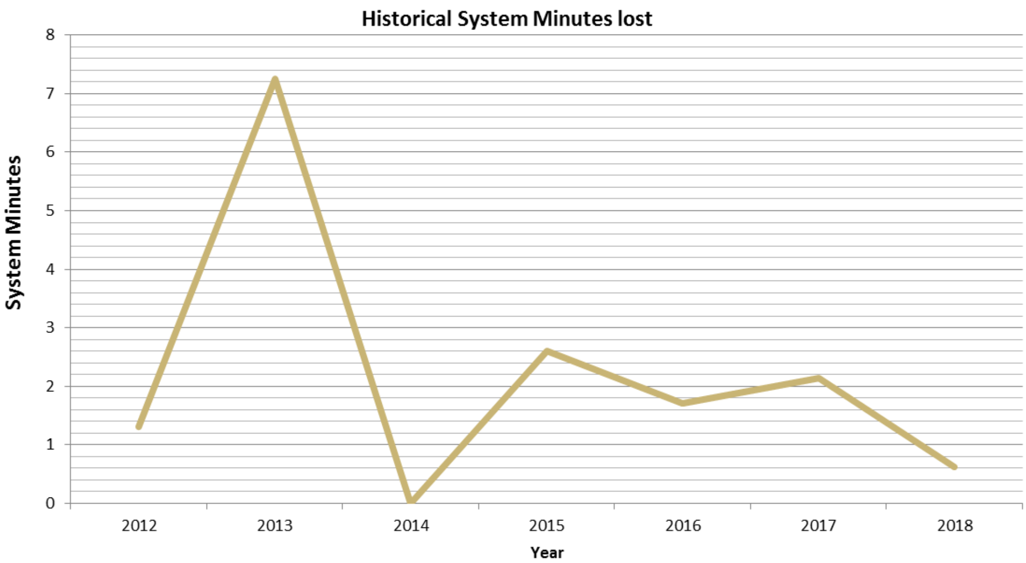

Figure 29: System minutes lost 2012 - 2018

5.3.6 Zone Clearance Ratio

The Zone Clearance Ratio (ZCR) is defined as the ratio of the number of short circuit, system faults, not cleared in Zone 1 to the total number of short circuit faults per year cleared by Main System protection. See Appendix A for further definition of Zones and ZCR.

In 2018, the ZCR was 0. There were 5 system faults cleared by protection on the main system. Of the 5 faults, all 5 were cleared in zone 1.

5.4 Quality of Service

Quality of service is measured with reference to system voltage and frequency.

5.4.1 Voltage

The Electricity Safety, Quality and Continuity Regulations (Northern Ireland) 2012 details the requirements for the management of voltage in Northern Ireland.

Part 7, paragraph 28 permit variations not exceeding 10% for operating voltages of 110 kV or higher. As well as adhering to legislation, SONI also operates the transmission system in such a way as to comply with the Operating Security Standards[7], acceptable step changes in voltages are detailed in Table 10.

Table 10: Voltage step change limits in operational timescales

Transmission System secured events or switching event	Voltage fall	Voltage rise
Following loss of single circuit	-6%	+6%
Following loss of double circuit overhead line	-10%	+6%

5.4.2 Voltage Excursions

There were no voltage excursions exceeding these limits in 2018.

5.4.3 Frequency

SONI is required to manage the frequency of the power system. Power system frequency is a measure of balance between the electrical demand on the network and the amount of energy

[7] SONI Operating Security Standards

being generated. The Electricity Safety, Quality and Continuity Regulations (Northern Ireland) 2012 details the requirements for the management of Frequency in Northern Ireland.

Part 7, paragraph 28 of the regulations permits a frequency variation of up to 0.5 Hz above or below 50 Hz. In line with previous publications this report contains details of frequency events where the frequency has dropped below 49.6 Hz or greater than 50.5 Hz. There were four reportable frequency excursions in Northern Ireland in 2018. Graphs in Appendix 2 contain traces of system frequency as well as raw and averaged rate of change of frequency data.

5.4.4 Frequency Excursions

Table 11: Frequency Excursions in 2018

Cause of Incident	Date	Time	MW Lost	Pre-incident Frequency (Hz)	Nadir (Hz)	Minimum Frequency in POR Timeframe (Hz)	Maximum Rate of Change of Frequency (Hz/s)	t<49.6 Hz (s)	t<49.5 Hz (s)	N-S Tie Line Flow (MW)
Dublin Bay DB1	17/01/2018	12:03:23	391	50.00	49.351	49.519	-0.28	4.8	3.3	-16
Tynagh TYC	15/06/2018	21:14:11	377	49.96	49.596	49.674	-0.14	0.5	0.0	-267
Aghada AD2	12/07/2018	00:39:18	342	49.97	49.561	49.670	-0.20	2.0	0.0	179
Whitegate WG1	22/12/2018	06:53:40	316	49.99	49.565	49.723	-0.29	1.7	0.0	-49

Definitions

Time	Considered to be when the frequency falls through 49.8 Hz
Pre-incident Frequency	Average system frequency between t – 60 seconds and t – 30 seconds
Nadir	Minimum system frequency from t 0 to t + 6 minutes
Minimum Frequency in POR Timeframe	Minimum frequency during POR timeframe from t + 5 seconds to t + 15 seconds
Maximum Rate of Change of Frequency	Maximum rate of change of frequency calculated over 500 ms during the period t – 5 seconds to t + 30 seconds
N-S Tie Line Flow	Flow on the N-S t – 5 seconds (+ve represents an export from Northern Ireland)

5.4.5 Historical Frequency Excursions

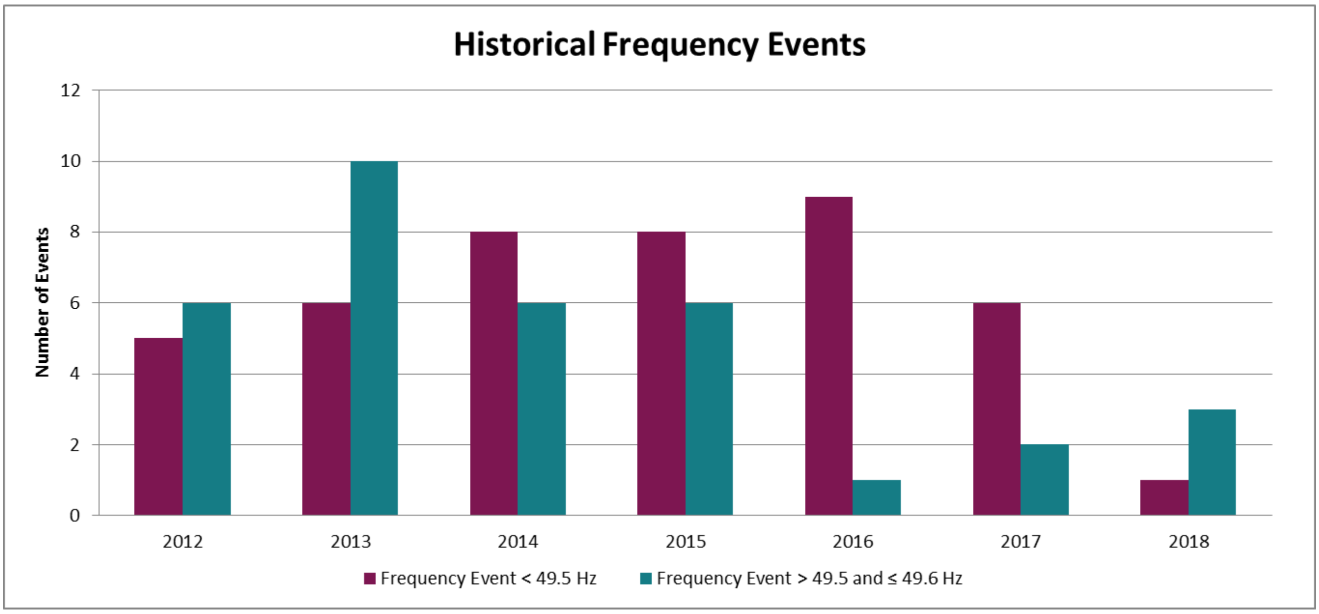

Figure 30: Historic Frequency Excursions 2012-2018

6. Appendix 1 Glossary

6.1 DCEF

Directional comparison earth fault. A teleprotection scheme that allows accelerated tripping by exchanging permit and receive signals for earth faults in a relay's forward direction.

6.2 Disturbance

A system disturbance is defined as one or more related faults and their consequences which occur either simultaneously or over a period of time. These incidents are grouped in a single system disturbance report under the highest voltage involved.

6.3 Fault

Any abnormal event causing or requiring the tripping of a Main System circuit breaker automatically within the Main System. Any abnormal event causing or requiring the closing of a Main System circuit breaker automatically within the Main System. Any abnormal event causing or requiring the tripping of an MV circuit breaker automatically by under frequency relay operation.

6.4 Main system: EirGrid

The main transmission system includes: the 400 kV, 220 kV and 110 kV overhead line (OHL) and underground cable (UGC) network, the 400 kV, 220 kV and 110 kV busbars and couplers, the 400/220 kV and 220/110 kV coupling transformers (with the exception of those feeding the Dublin city 110 kV network). It also includes the 275 kV ESB/NIE Networks interconnector as far as the border with Northern Ireland, and the associated 275/220 kV transformers. The main transmission system does not include the Dublin city 110 kV network or the 220/110 kV coupling transformers at Carrickmines, Inchicore and Poolbeg. The HV circuit breakers of tail connected lines and directly connected transformers (DSO load, directly connected industrial customer load, generator and HVDC interconnector transformers) are part of the main transmission system thus faults on these lines and transformers, which cause transmission system circuit breakers to be tripped, are reported.

6.5 Main system: SONI

The main transmission system includes: the 275 kV and 110 kV OHL and UGC network, the 275 kV and 110 kV busbars and couplers, the 275/110 kV interbus transformers, and all 110/33 kV load transformers (aka main transformers). It also includes the 275 kV ESB/NIE Networks interconnector as far as the border with Ireland. The HV circuit breakers of directly connected transformers (generator and HVDC interconnector transformers) are part of the main transmission system thus faults on these transformers, which cause transmission system circuit breakers to be tripped, are reported.

6.6 Major incident

A major incident is one which results in the loss of greater than or equal to one system minute as a result of a single system disturbance.

6.7 MVA Minute Lost

Amount of Power (Mega Volt-Amp) not supplied during an interruption of one minute.

6.8 Non main system/outside the main system: EirGrid

All HV plant on the Irish electricity network that does not form part of the main system: the Dublin 110 kV network (controlled by the DSO at the northern distribution control centre (NDCC). The MV system in Ireland is controlled by the SDCC in Wilton and the NDCC in Leopardstown), all DSO and industrial customer load transformers, all IPP generator transformers, and all plant on the NIE Networks owned, SONI controlled, HV system in Northern Ireland.

6.9 Non main system/outside the main system: SONI

All HV plant connected to the Northern Irish electricity network that does not form part of the main system: all IPP generator transformers, HVDC interconnector transformers, and all plant on the ESB owned, EirGrid controlled, HV system in Ireland

6.10 Non System Fault

Any unplanned circuit breaker operation resulting from a cause other than a system fault or incorrect manual operation from a control point.

6.11 Permanent Fault

A fault is permanent if the component or unit is damaged and cannot be restored to service until repair or replacement is completed. An overhead line trips and stays out of service due to the absence or outage of reclosing facilities; the fault is permanent if maintenance staff have to carry out equipment repairs or replacement before the line is returned to service. A protection setting change is required on the piece of plant before or after it is switched in following a fault.

6.12 POTT

Permissive overreach transfer trip. A distance teleprotection scheme that allows accelerated tripping by exchanging permit and receive signals for faults in a relay's zone 2.

6.13 Protection - Correct Operation

The operation is correct if a fault is cleared by the protection (in any time step) such that the correct circuit breakers open and no other circuit breaker opens.

6.14 Protection - Incorrect Operation

The operation is incorrect if, while a fault is being cleared, a circuit breaker is opened which should not have opened or a circuit breaker remains closed which should have opened.

6.15 PUTT

Permissive underreach transfer trip. A distance teleprotection scheme that allows accelerated tripping by receiving a signal for a fault in a relay's forward direction.

6.16 STAR Scheme

Short Term Active Response was a scheme operated by EirGrid whereby large electricity consumers voluntarily contracted to make their load available for short term interruptions. This service provided EirGrid with approximately 45 MW of static reserve that is utilised in the event of system frequency falling below 49.3 Hz. The scheme was discontinued in April 2018.

6.17 Sustained Interruption

A sustained interruption is one which lasts for more than one minute.

6.18 System Fault

Any fault or system abnormality which involves, or is the result of failure of primary electrical apparatus and which requires the disconnection of the affected equipment from the system by the automatic tripping of the associated circuit breaker.

6.19 System Minute

A measure of the energy not supplied for a disturbance. The metric takes account of the load lost (MW), duration of disconnection (Minutes) and peak system demand (MW), to allow for historical comparison. For example, if 300 MW were lost for 10 minutes and the system peak was 3000 MW, this would represent one System Minute.

System Minutes = (Load MW x Duration mins) / (System Peak MW) = (300 x 10) / 3000 = 1

6.20 Transient Fault

A fault is transient if the unit or component is undamaged and is restored to service through manual switching operations, or rapid automatic reclosure on overhead lines, without repair being performed, but possibly with on-site inspection.

6.21 Zone Clearance Ratio

The Zone Clearance Ratio is defined as the ratio of the number of short circuit faults not cleared in Zone 1 to the total number of short circuit faults per year. The more faults cleared in Zone 1, the quicker they are taken off the power system which reduces the risk of system instability, plant damage and injury to personnel.

6.22 Zones of Protection

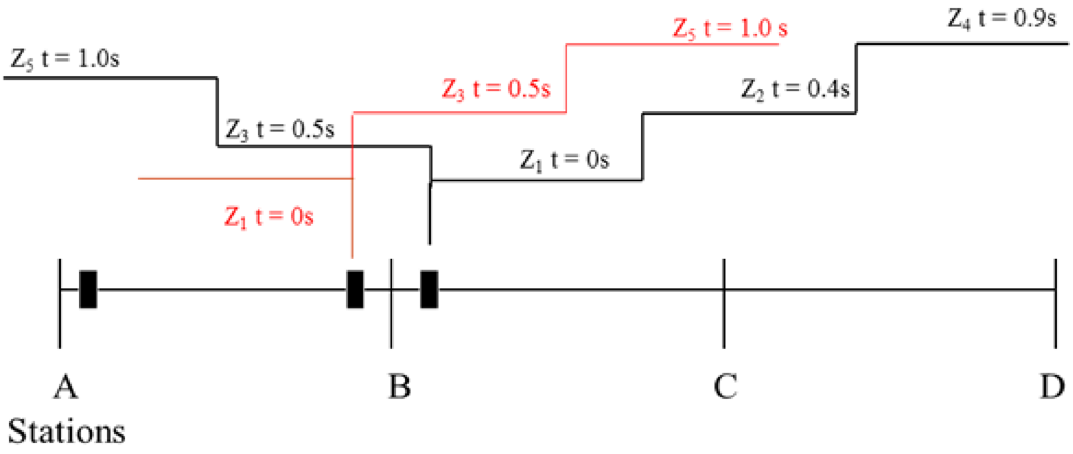

Figure 31: Zones of Protection

Zone 1 on an impedance (distance) relay is the primary protection zone and in the case of an overhead line is set to 70 - 85% of the circuit length depending on the location of the circuit in the transmission network. There is no time delay for the relay to pick up when a fault occurs within the Zone 1 reach, as shown in Figure 31. Typical Zone 1 clearance times are 50 to 150 ms.

Zone 2 on an impedance relay is used as a backup protection zone and is set to 100% of the circuit length plus 20 - 50% of the length of the shortest feeder at the remote end of the protected circuit. A delay of approximately 400 ms is applied in Zone 2 settings and so typical Zone 2 fault clearance times are 450 to 550 ms.

Zone 3 on an impedance relay is used as a backup protection zone and is set to 20 - 50% of the length of the shortest feeder in the reverse direction. A delay of approximately 500 ms is applied in Zone 3 settings and so typical Zone 3 fault clearance times are 550 to 650 ms.

Zone 4 is the third forward step of a distance scheme with a time delay of approximately 900 ms.

Zone 5 is the second reverse step of a distance protection scheme with a time delay of approximately 1.1 seconds.

7. Appendix 2 All Island Frequency Excursion Graphs

Table 12: All Island Frequency Excursion Incidents

Cause of Incident	Date
Dublin Bay 1	17/01/2018
Tynagh TYC	15/06/2018
Aghada AD2	12/07/2018
Whitegate WG1	22/12/2018

7.1 Dublin Bay – 17/01/2018

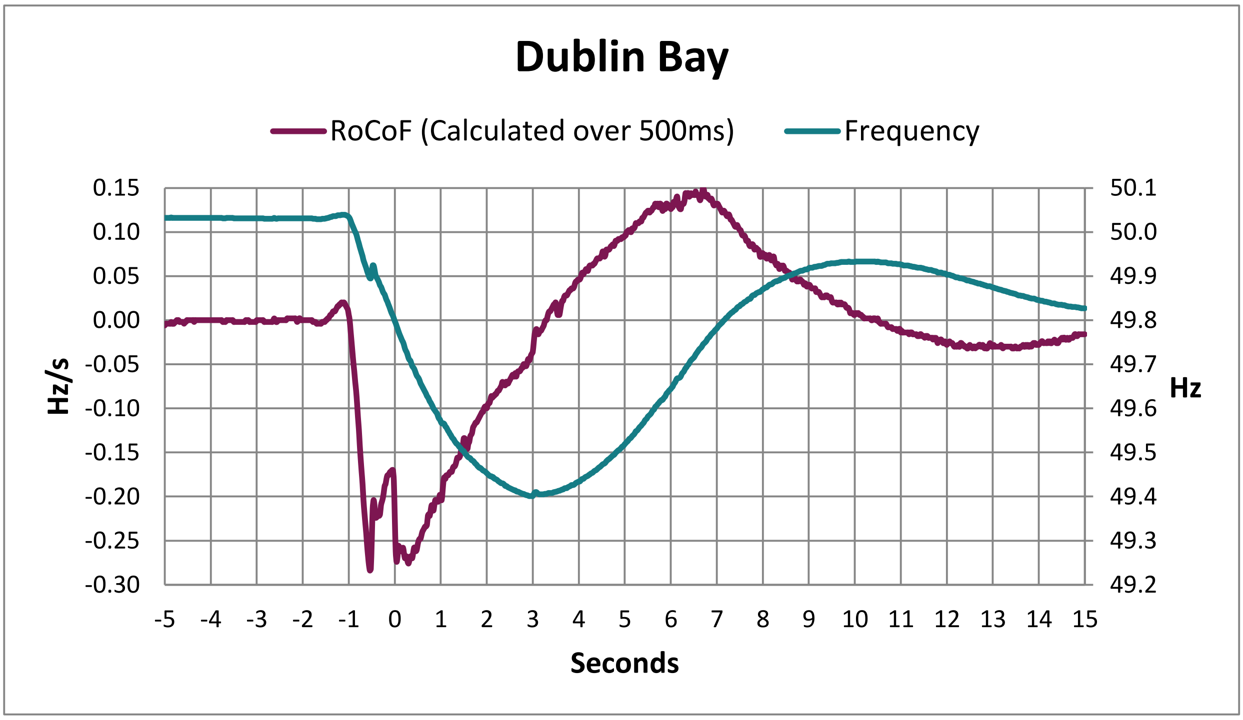

Figure 32: Dublin Bay Frequency Excursion Incident

7.2 Tynagh – 15/06/2018

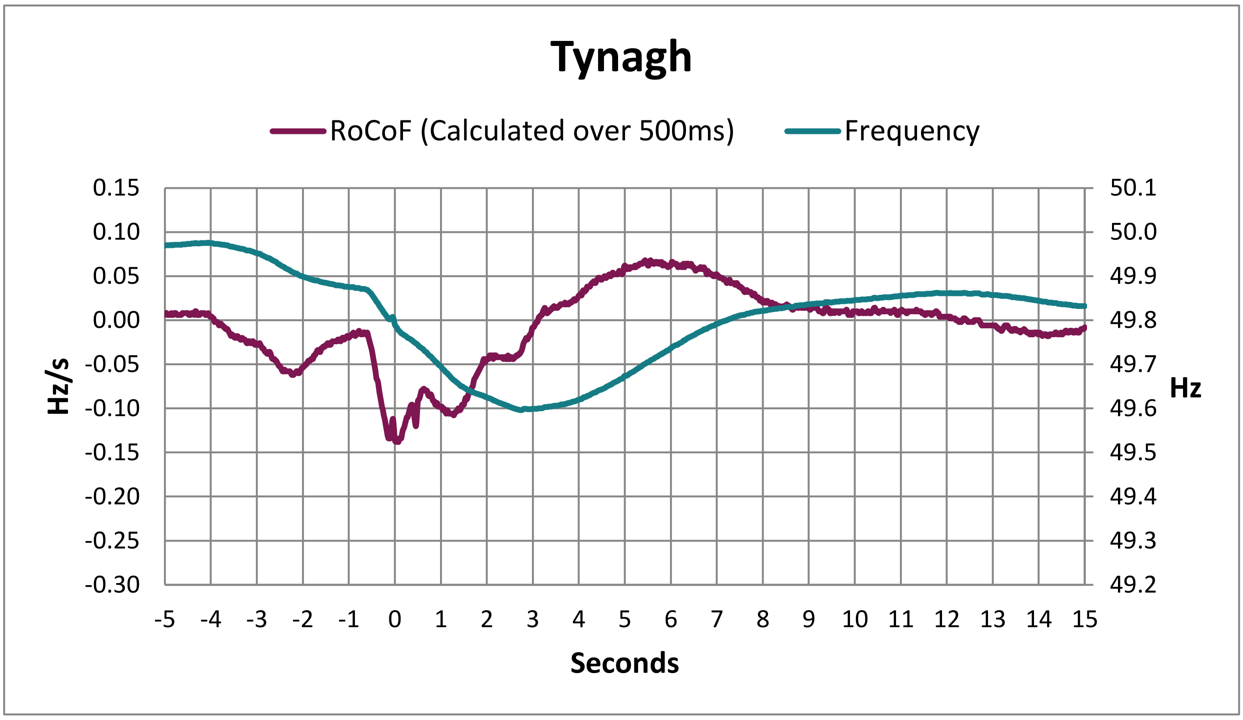

Figure 33: Tynagh Frequency Excursion Incident

7.3 Aghada Unit 2 12/07/2018

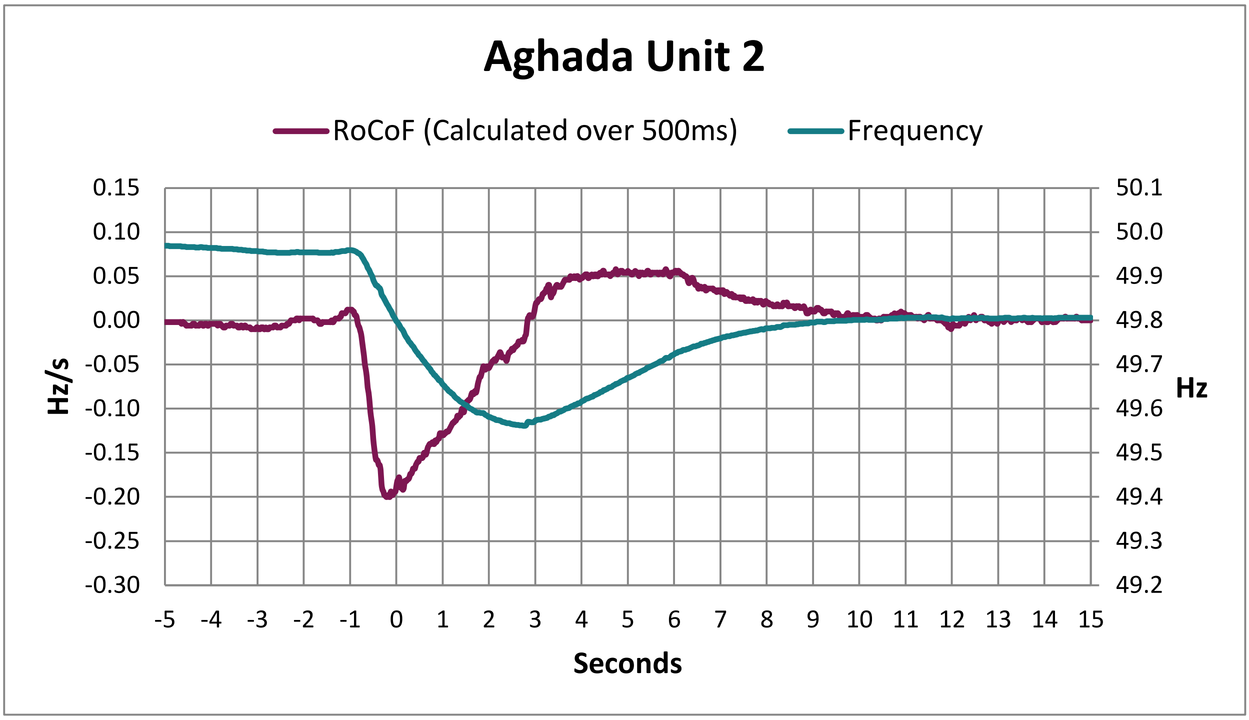

Figure 34: Aghada Unit 2 Frequency Excursion Incident

7.4 Whitegate 1 – 22/12/2018

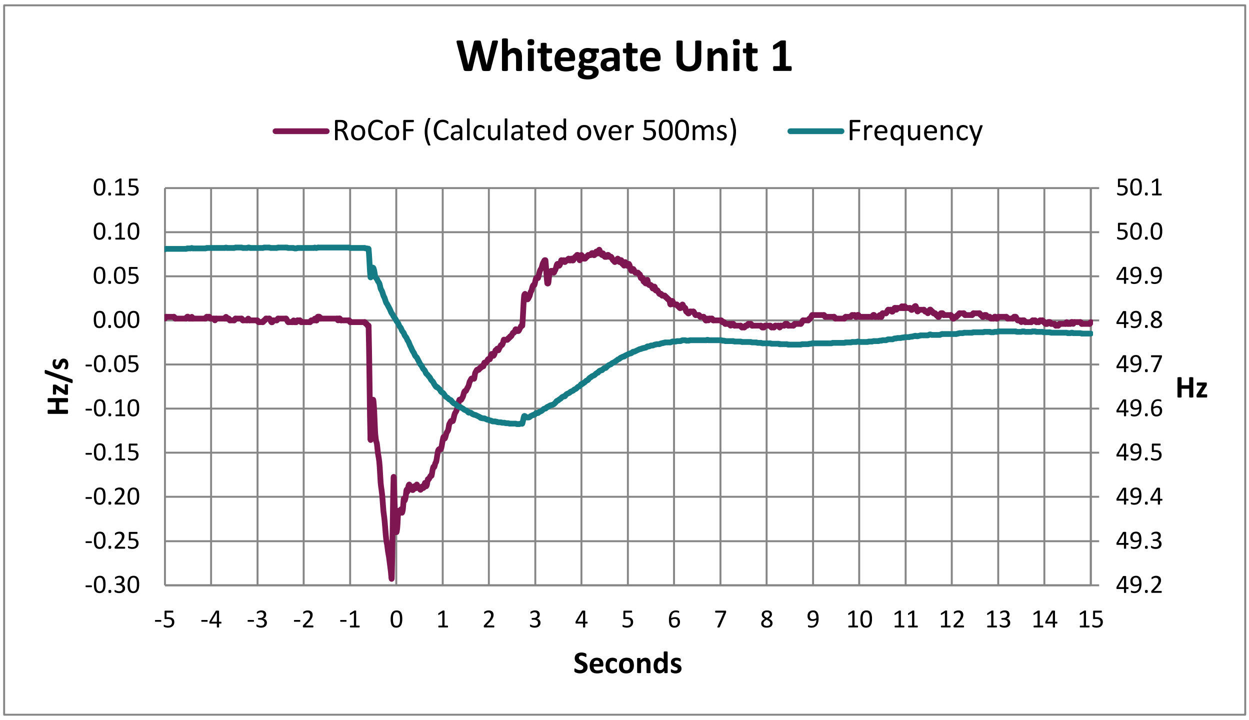

Figure 35: Whitegate Unit 1 Frequency Excursion Incident

8. Appendix 3 All Island Fully Dispatchable Generation Plant

Table 13: All Island Fully Dispatchable Generation Plant

Company	Unit	Capacity (MW)	Fuel	365-day Rolling Availability %
AC Automation	AC - ACA	8	DSU	85.15
Activation Energy	AEDSU - AE1	77	DSU	31.23
	AEDSU - AE2	7.986	DSU	36.14
	AEDSU - AE3	13.969	DSU	56.64
	AEDSU - AE4	10.782	DSU	0
	AEDSU - AE5	15.3	DSU	55.12
	AEDSU - EN5	5.533	DSU	56.12
	AEDSU - EN6	9.862	DSU	57.66
Activation Energy Ltd (NI)	AE_DSU_NI - AEA	9	DSU	69.23
AES	Ballylumford - B10	94	Gas / Distillate Oil	86.92
	Ballylumford – B31	249	Gas / Distillate Oil	49.85
	Ballylumford – B32	249	Gas / Distillate Oil	87.6
	Ballylumford - BPS4	144	Gas / Distillate Oil	85.58
	Ballylumford - BPS5	147	Gas / Distillate Oil	99.98
	Ballylumford - BGT1	58	Distillate	97.91
	Ballylumford - BGT2	58	Distillate	97.55
	Kilroot - KPS1	256	Coal / Heavy Fuel Oil	95.23
	Kilroot - KPS2	258	Coal / Heavy Fuel Oil	88.77
	Kilroot - KGT1	29	Distillate	98.6
	Kilroot - KGT2	29	Distillate	97.79
	Kilroot - KGT3	42	Distillate	94.53
	Kilroot - KGT4	42	Distillate	66.66
Aughinish Alumina Ltd	Seal Rock - SK3	85	Gas / Distillate Oil	89.48
	Seal Rock - SK4	85	Gas / Distillate Oil	90.42
Bord Gáis	Whitegate - WG1	444	Gas / Distillate Oil	65.61
Contour Global	Contour - CGA	12.08	Gas	94.65
Coolkeeragh ESB	Coolkeeragh - C30	408	Gas / Distillate Oil	90.88
	Coolkeeragh - CG8	53	Distillate	97.17
DAE Virtual Power Plant	DAE VPP - DP1	18.61	DSU	74.15
	DAE VPP - DP2	25.8	DSU	25.46
Dublin Waste To Energy	Dublin Waste - DW1	61.5	Waste to Energy	85.4

Company	Unit	Capacity (MW)	Fuel	365-day Rolling Availability %
Edenderry Power Ltd	Edenderry - ED1	118	Peat	87.55
	Edenderry - ED3	58	Gas / Distillate Oil	99.88
	Edenderry - ED5	58	Gas / Distillate Oil	99.49
Electric Ireland DSU	Electric Irl - EI1	19.6	DSU	78.54
Electricity Exchange Limited	Elect Exchng - EE1	38.603	DSU	57.13
	Elect Exchng - EE2	17.4365	DSU	54.43
	Elect Exchng - EE3	7.458	DSU	37.72
	Elect Exchng - EE4	8.614	DSU	66.12
	Elect Exchng - EE5	7.322	DSU	51.55
Empower Generation Limited	EmpowerAGU - EMP	3	Distillate	100
Endeco Technologies	Endeco T Ltd - EC1	39.187	DSU	56.21
	Endeco T Ltd - EC2	11.018	DSU	39.51
	Endeco T Ltd - EC5	15.836	DSU	49.07
	Endeco T NI - ECA	11	DSU	44.3
Energy Trading Ireland	ETI Ltd (NI) - ETB	9	DSU	64.87
	ETI Ltd (NI) - ETD	5	DSU	17.99
	ETI Ltd (NI) - ETR	19	DSU	48.88
	Ener Trd Irl - ET1	12.61	DSU	69.9
Evermore Renewable Energy	Lisahally - LPS	17.6	Biomass	71.02
Indaver	Indaver - IW1	17	Waste to Energy	90.05
IPOWER	iPower AGU - AGU	74	Distillate	94.98
Powerhouse Generation Ltd.	Powerhouse G - PG1	11.463	DSU	73.24
Powerhouse Generation Ltd. (NI)	PHG - PH1	31	DSU	66.59
SSE Generation Ireland	Great Island - GI4	461	Gas / Distillate Oil	71.97
	Rhode - RP1	52	Distillate	97.11
	Rhode - RP2	52	Distillate	97.94
	Tarbert - TB1	54	Heavy Fuel Oil	99.69
	Tarbert - TB2	54	Heavy Fuel Oil	97.58
	Tarbert - TB3	241	Heavy Fuel Oil	99.77
	Tarbert - TB4	243	Heavy Fuel Oil	92.42
	Tawnaghmore - TP1	52	Distillate	98.63
	Tawnaghmore - TP3	52	Distillate	97.89
SYNERGEN	Dublin Bay - DB1	405	Gas / Distillate Oil	98.12
Tynagh Energy Ltd	Tynagh - TYC	384	Gas / Distillate Oil	93.81
Viridian Power and Energy	Huntstown - HN2	400	Gas / Distillate Oil	96.04
	Huntstown - HNC	342	Gas / Distillate Oil	93
	Viridian DSU - VE1	20.067	DSU	54.42

	Viridian DSU - VE2	6.3	DSU	49.32

Company	Unit	Capacity (MW)	Fuel	365-day Rolling Availability %
ESB Power Generation	Ardnacrusha - AA1	21	Hydro	66.32
	Ardnacrusha - AA2	22	Hydro	68.53
	Ardnacrusha - AA3	19	Hydro	69.57
	Ardnacrusha - AA4	24	Hydro	68.78
	Aghada - AD2	431	Gas / Distillate Oil	96.21
	Aghada - AT11	90	Gas / Distillate Oil	98.07
	Aghada - AT12	90	Gas / Distillate Oil	97.55
	Aghada - AT14	90	Gas / Distillate Oil	92.04
	Erne - ER1	10	Hydro	88.24
	Erne - ER2	10	Hydro	93.08
	Erne - ER3	22.5	Hydro	92
	Erne - ER4	22.5	Hydro	98.86
	Lee - LE1	15	Hydro	98.61
	Lee - LE2	4	Hydro	78.19
	Lee - LE3	8	Hydro	93.6
	Liffey - LI1	15	Hydro	92.79
	Liffey - LI2	15	Hydro	92.81
	Liffey - LI4	4	Hydro	92.85
	Liffey - LI5	4	Hydro	93.78
	Lough Ree - LR4	91	Peat	88.6
	Moneypoint - MP1	285	Coal / Heavy Fuel Oil	56.44
	Moneypoint - MP2	285	Coal / Heavy Fuel Oil	69.02
	Moneypoint - MP3	285	Coal / Heavy Fuel Oil	29.99
	North Wall - NW5	104	Gas / Distillate Oil	88.1
	Poolbeg - PBA	154	Gas / Distillate Oil	88.49
	Poolbeg - PBB	146	Gas / Distillate Oil	87.82
	Turlough H - TH1	73	Hydro - Pumped Storage	96.15
	Turlough H - TH2	73	Hydro - Pumped Storage	96.25
	Turlough H - TH3	73	Hydro - Pumped Storage	95.27
	Turlough H - TH4	73	Hydro - Pumped Storage	92.29
	West Offaly - WO4	137	Peat	70.78

9. Appendix 4 EirGrid Maintenance Policy Terms

The following summarises the main terms and activities in the asset maintenance policy as operated by EirGrid[8]. The need to ensure that equipment continues to operate in a safe, secure, economic and reliable manner, while minimising life cycle costs, underlies the principles behind this asset maintenance policy. Effective maintenance management balances the costs of repair, replacement and refurbishment against the consequences of asset failure.

There are four primary maintenance categories:

1. Preventative/Routine: Preventive/routine maintenance is planned at predetermined intervals to reduce the likelihood of equipment degradation which could lead to plant failure e.g. condition assessment. This type of maintenance is planned in advance and the frequencies of these activities are pre-determined by the EirGrid Asset Maintenance Policy
2. Corrective: Corrective maintenance may consist of repair, restoration or replacement of equipment before functional failure. Corrective maintenance requirements are identified through regular inspections. The aim of routine inspections is to identify the potential for failure in time for the solution to be planned and scheduled and then performed during the next available outage.
3. Fault: Fault maintenance includes activities arising from unexpected equipment failure in service.
4. Statutory Maintenance: Maintenance which is carried out to facilitate statutory requirements e.g. Pressure Vessel Inspections, bund inspections.

Please refer to the 'Guide to Transmission Equipment Maintenance' which is published on the EirGrid website for further information[9].

[8] In Northern Ireland maintenance policy for the transmission system is the responsibility of NIE Networks as licenced Transmission Owner.

[9] www.eirgridgroup.com/site-files/library/EirGrid/Guide-to-Transmission-Equipment-Maintenance-March-2018.pdf

10. Appendix 5 Formulae

10.1 Availability & Unavailability Formula

Availability of 110kV, 220 kV, 275 kV and 400 kV lines:

$$\text{System Availability} = 1 - \frac{\sum_{i=1}^{i=n} \text{Duration of Outage (i)} * \text{Length of Line (i)}}{\sum_{j=1}^{j=m} \text{Length of Line (j)} * \text{Days in a Year}}$$

Where: n = The total number of lines (at that voltage level) for which outages occurred

m = The total number of lines at that voltage level

Availability of 220 kV/110 kV, 275 kV/220 kV and 400 kV/220 kV transformers:

$$\text{System Availability} = 1 - \frac{\sum_{i=1}^{i=n} \text{Duration of Outage (i)} * \text{MVA of Transformer (i)}}{\sum_{j=1}^{j=m} \text{MVA of Transformer (j)} * \text{Days in a Year}}$$

Where: n = The total number of transformers for which outages occurred
m = The total number of transformers at that voltage level

System Unavailability:

$$\text{System Unavailability} = 1 - \frac{\sum \text{Hours each Circuit is Available}}{\text{Number of Circuits} * \text{Hours in Period}}$$

The equation above is the same as that used by OFGEM (The Office of Gas and Electricity Markets) in the UK.

10.2 System Minute Formula

System Minutes:

$$\text{System Minutes} = \frac{\text{Energy not supplied MW Minutes}}{\text{Power at System Peak}}$$

$$\text{System Minutes} = \frac{\text{(MVA Minutes)} * \text{(Power Factor)}}{\text{System Peak to Date}}$$

Where: Power factor = 0.9