All-Island Transmission System Performance Report

2017

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 2017. This report contains transmission system data and performance statistics for the transmission system in Ireland and Northern Ireland for the year 2017 (1st January 2017 – 31st December 2017). The report includes both transmission system performance statistics and a number of high level transmission system characteristics.

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 2017 against the criteria approved by the CRU,
- Section 5 details the performance of the SONI TSO business during 2017 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 2017 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 6531 MW on Friday the 15th December 2017. The minimum all-island demand was 2427 MW and occurred on Tuesday the 1st August.
- The all-island installed capacity of conventional, dispatchable generation in 2017 was 9526 MW.
- In 2017 the system frequency was operated within 49.9 Hz and 50.1 Hz for 99.6% of the time.
- In 2017 the system was operated within the acceptable operating security standards

Ireland

- In 2017 the availability of the East West Interconnector was 85%.
- The average plant availability in Ireland in 2017 was 94.56%
- The System Minutes lost for 2017, attributable to EirGrid, was 0.300.

Northern Ireland

- The availability of the Moyle Interconnector for 2017 was 69.69%.
- The average availability of the Northern Ireland transmission system in 2017 was 96.3%
- The System Minutes lost for 2017, attributable to SONI, was 2.133.

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 and small-scale generation as well as pumped storage units on the island.

Table 1: Total Exported Energy 2016 & 2017

	2016	2017
All-Island Total Exported Energy [GWh]	36357	36627
Ireland Total Exported Energy [GWh]	27631	28157
Northern Ireland Total Exported Energy [GWh]	8725	8470

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 2017 was 6531 MW and occurred at 17:30 on Friday 15th of 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 2017 a minimum all-island demand of 2427 MW was recorded at 05:45 on Tuesday 1st of August.

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 3297 MW was achieved on the 29th of December. Table 2 provides a summary of the system records for 2016 and 2017.

Table 2: System Records 2016 & 2017

	2016	2017
Winter Peak Demand [MW]	6375	6531
Minimum Summer Night Valley [MW]	2370	2427
Maximum Wind Generation [MW]	2812	3297

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[1].

The all-Island installed capacity of conventional, dispatchable generation in December 2017 was 9525 MW (7281 MW in Ireland and 2244 MW in Northern Ireland). This does not include any import capacity from the Moyle Interconnector or the East West Interconnector.

The all-island installed capacity of wind generation in 2017 was 4471 MW (3311 MW in Ireland and 1160 MW in Northern Ireland).

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

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

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[2]. Figure 1 shows the daily and 365-day rolling average availability for 2017.

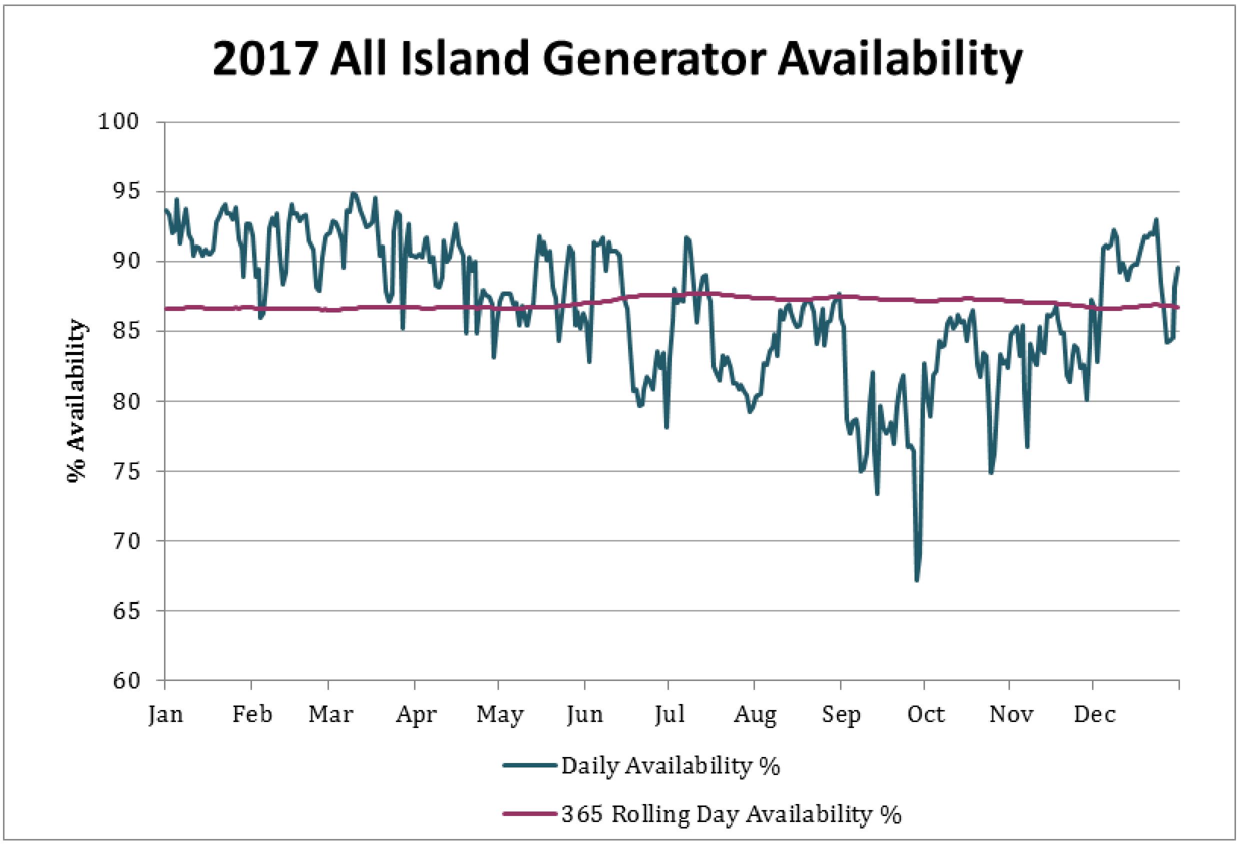


Figure 1: Generation System Availability 2017

- The average daily generation system availability in 2017 was 86.78%
- The maximum daily generation system availability in 2017 was 94.87%.
- The minimum daily generation system availability in 2017 was 61.78%.

[2] 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.

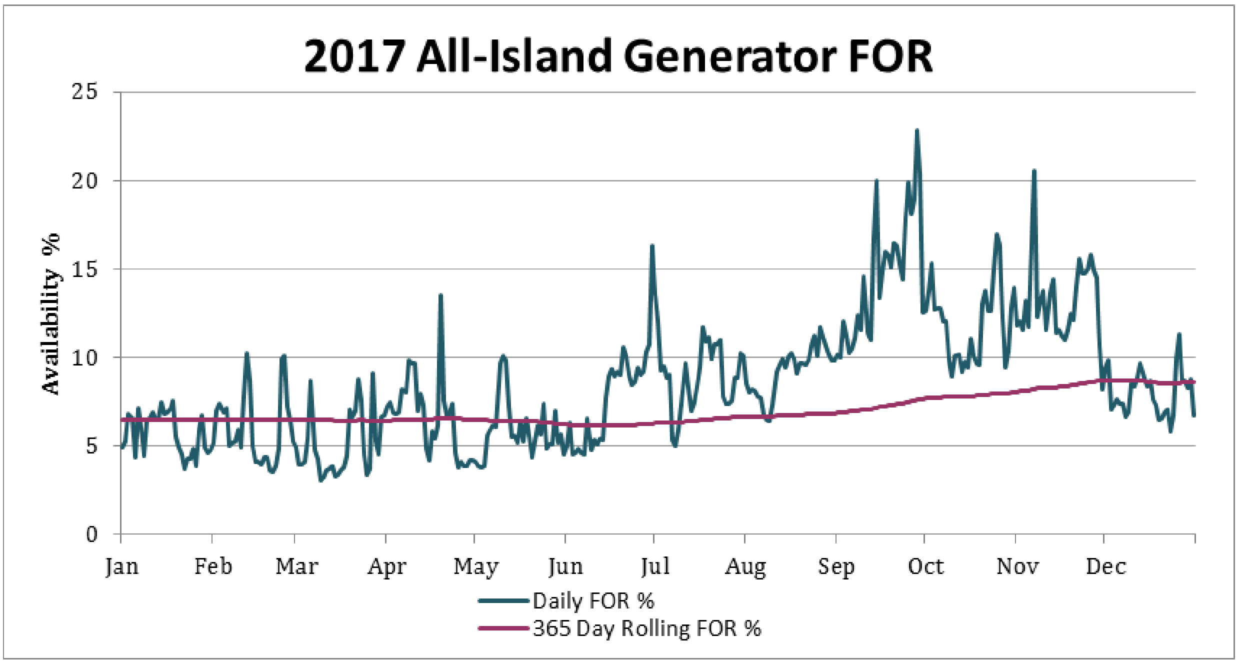


Figure 2: Generation System Forced Outage Rate 2017

- The average daily generation system forced outage rate in 2017 was 8.6%.
- The maximum daily generation system forced outage rate in 2017 was 22.89%.
- The minimum daily generation system forced outage rate in 2017 was 3.04%.

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.

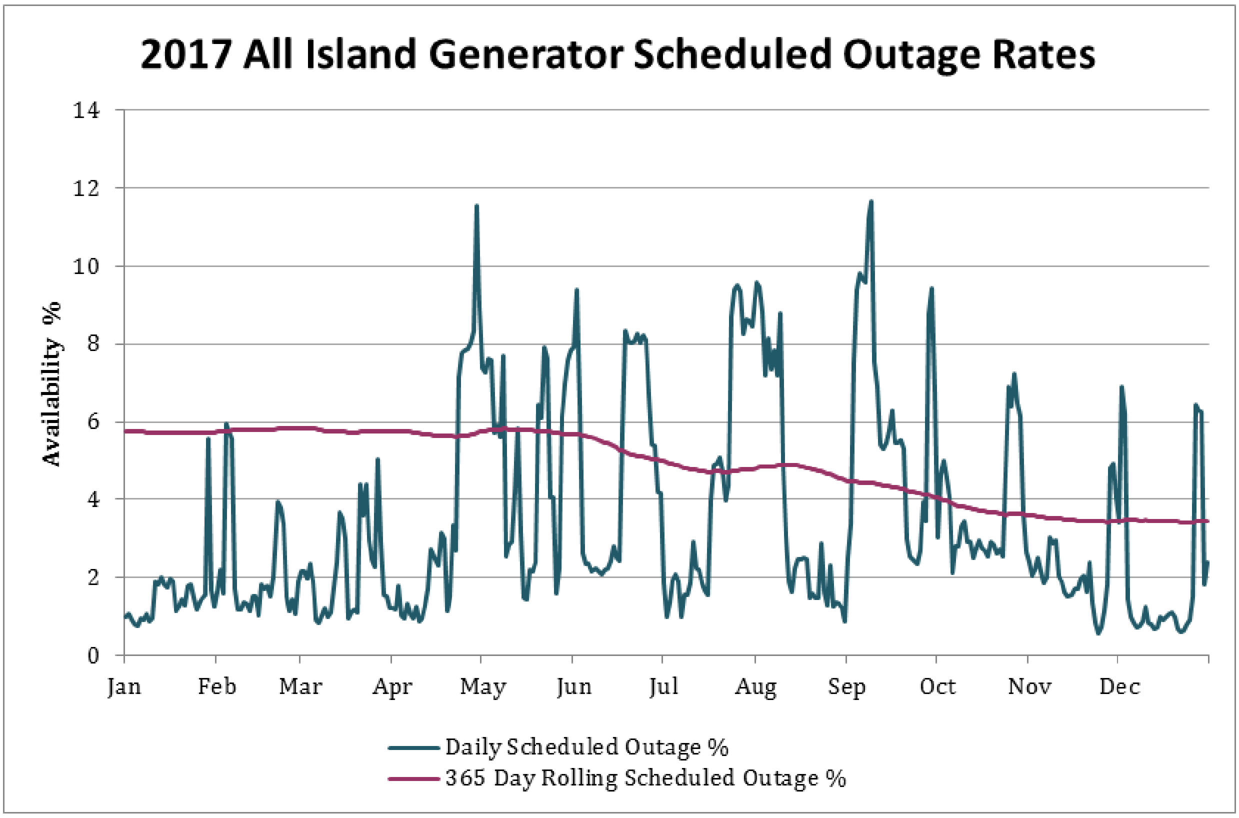


Figure 3: Generation System Scheduled Outage Rate 2017

- The average daily generation system scheduled outage rate in 2017 was 3.46%.
- The maximum daily generation system scheduled outage rate in 2017 was 11.68%.
- The minimum daily generation system scheduled outage rate in 2017 was 0.57%.

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

The system was operated at all times within the acceptable operating security standards. All security of supply key performance indicators (KPIs) were achieved throughout the year.

The system minutes lost as a result of faults on the main system was 0.3 in 2017. 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 2017, the system frequency was within the agreed limits 99.5% of the time.

4.2 Grid Development and Maintenance

This section provides an overview of grid development activities in 2017.

4.2.1 Completed Capital Projects

The following capital projects were completed in 2017:

- Moneypoint-Kilpaddoge 220kV Cable
- Kinnegad - Mullingar 110kV Circuit
- Ennis-Booltiagh-Tullabrack T Moneypoint 110kV line uprate
- Ballynahulla 220kV Station
- Castlebar 110kV station
- Cloon 110kV station
- Balteau CTs Replacement
- West Galway 110kV GIS station
- Cauteen - Killonan 110kV Line Uprate
- Dunstown - Kellis 220kV line refurbishment

- Ryebrook 110kV GIS Station
- Cordal 110kV Station
- HV Line Tower Painting - South
- Dalton 110kV Station New Bay
- Ballynahulla 220kV station - 2nd 220/110kV transformer
- Charleville 110 kV Station
- Derryfrench - Tynagh 110kV Line Retirement
- Cauteen 110kV Station Shallow Works
- Flagford Srananagh 220 kV Line Conflict
- Corderry Shallow Connection Works
- Kilpaddoge 110kV Station Shallow Works
- Clonee 220kV Station
- Cloghran Phase 3
- Moneypoint WF Shallow Connection
- Garvagh Windfarm Phase 2
- Ennis 110kV Station Circuit Breaker replacements

4.2.2 New Connection Offers

Parties seeking a new connection to the transmission 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 2018/2019.

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 2017 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 in 2017

	Demand	Generation
Executed Connection Offer Agreements in 2017 [No.]	6	1
Executed Connection Offer Agreements in 2017 [Capacity]	362.05 MVA	80 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 2017.

Table 4: Demand & Generation Connections Energised in 2017

	Demand	Generation	WFPS & PV[3]
Connections Energised in 2017 [No.]	0	0	21
Connections Energised in 2017 [Capacity]	0 MVA	0 MW	506.35 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 generators connected to the distribution network. Note that demand customers are not currently certified by EirGrid and are therefore not included in the table.

[3] WFPS: Wind Farm Power Station , PV: Photovoltaic

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

Table 5: Customers Certified Operational in 2017

	Total No. of sites Certified Operational 2017	Total Demand of sites Certified Operational 2017
New WFPS	1	35.2 MW
New Conventional	1	61 MW
Reissued Op certs, including DSUs	18	675.76 MW

As of the end of 2017, there were a total of 19 Demand Side Units (DSU) certified as operational with a total capacity of 356.76 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[4]. 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. The TSO 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. 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 2017 for overhead lines, underground cables and transmission stations. In order to facilitate more maintenance work and

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

capital projects, EirGrid took the decision in 2015 to extend the transmission outage season by two months; work now takes place from the beginning of March and continues until the end of November.

Table 6: Maintenance Summary for 2017

Volume of Transmission Maintenance by Activity	Maintenance Programme Year End	Maintenance Completed
Overhead Line Maintenance		
Patrols (incl. Helicopter, climbing, infrared & Bolt) [km]	9,719	7,855
Timber Cutting [km]	67	54
Structure & Hardware Replacement [Number]	86	54
Insulator & Hardware Replacement [Number]	10	4
Underground Cable Maintenance		
Alarm Checks / Inspection [Number]	606	412
Station Maintenance		
Ordinary Service [Number]	287	224
Operational Tests [Number]	893	810
Condition Assessment of Switchgear [Number]	123	93
Tap Changer Inspection [Number]	7	6
Corrective Maintenance Tasks [No. of Tasks]	165	152

4.3 General System Performance

4.3.1 Under Frequency Load Shedding

There were no UFLS disturbances in 2017 which resulted in shedding of normal tariff load customers. Short term active response (STAR) interruptible load customers were disconnected on two occasions. Both disturbances were due to large generator trips; one in Ireland and one in Northern Ireland.

Table 7 provides a summary of each UFLS event. The relays to disconnect normal tariff customer load are only activated once the system frequency drops to 48.85 Hz. The time to recover to 49.9 Hz starts from 49.3 Hz, the point at which the STAR under frequency relays are activated. The lowest system frequency in 2017 was 49.249 Hz; during the second UFLS disturbance.

Table 7: Summary of UFLS disturbances in 2017: EirGrid

SDR No.	Date	Unit	MW	Freq, Hz	≥49.9 Hz, minutes	MVA Minutes	STAR SM	NT SM
T42/2017	24/09/17	Gen	393	49.309	6.69	78.97	0.013462	0
T61/2017	27/11/17	Gen	425	49.249	0.17	63.18	0.010772	0

The upper limit for activation of STAR schemes is 20 events per year. The number of STAR events each year since 2004 is presented in Figure 4. The mean over this period was 2.8 events per year. System minutes lost due to activation of the STAR scheme are not attributable to EirGrid due to STAR being a pre-existing contractual arrangement with the customers for disconnection of their load.

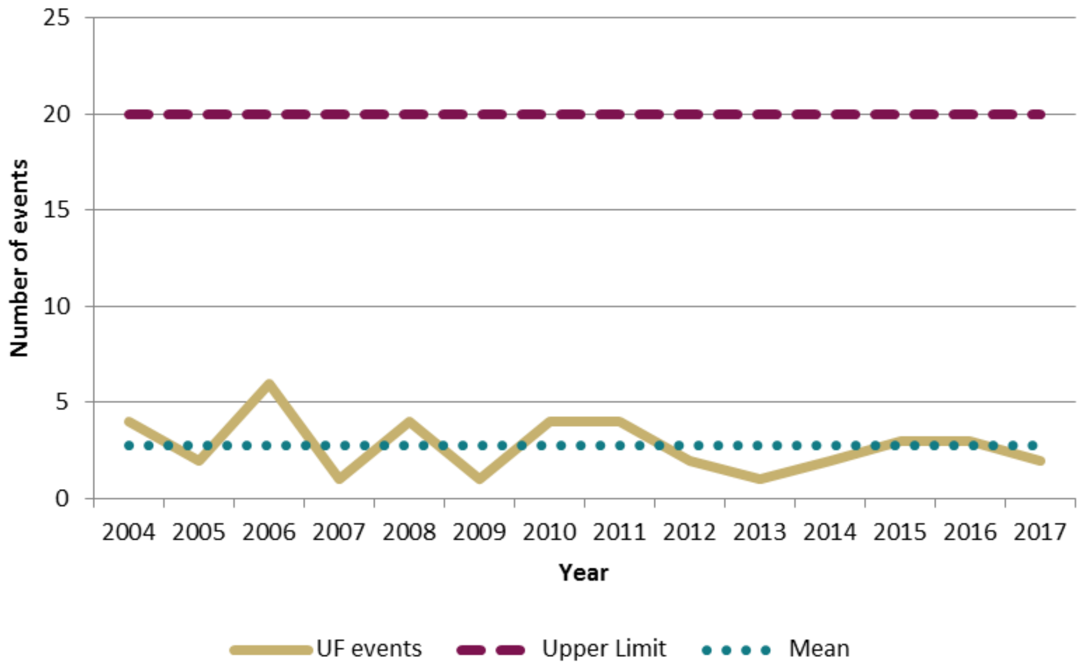


Figure 4: Number of STAR events 2004 - 2017

4.3.2 Under Voltage Load Shedding

There was no incident of Under Voltage Load Shedding in 2017.

4.4 System Minutes Lost

The total system minutes lost (SML) for 2017, attributable to EirGrid, was 0.300.

These 0.300 system minutes lost for 2017 were as a result of faults on the main system; no system minutes were lost due to the disconnection of normal tariff load customers during UFLS disturbances in 2017. The trend of system minutes lost since 2003 is shown in Figure 5, with incentive target areas and deadband, as provided by CRU.

In 2017, the total system minutes lost was below the threshold required to be awarded the full incentive amount by CRU.

The central target provided up to 2010 was replaced with a deadband in 2011[5]. The deadband is between 1.5 SML and 3.0 SML, where there is neither penalty nor incentive. EirGrid is awarded one fifth of the incentive amount for every 0.1 SML below 1.5 SML, down to 1.0 SML. EirGrid is penalised one fifth of the incentive amount for every 0.1 SML above 3.0 SML, up to a maximum penalty at 3.5 SML.

The average number of system minutes lost since 2003, attributable to EirGrid, was 1.115 with a standard deviation of 1.229.

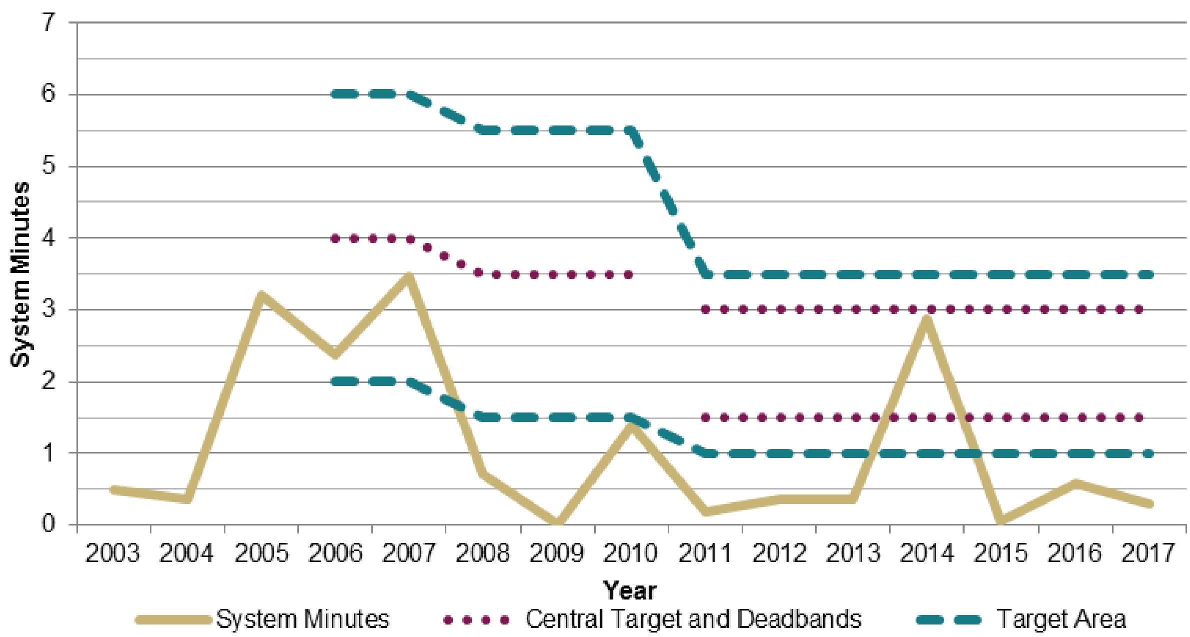


Figure 5: System minutes lost and associated targets 2003 - 2017: EirGrid

[5] CER11128: Decision on 2011/2012 Transmission Incentives

4.5 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 2017, the zone clearance ratio was zero. That is, 100% of faults were cleared in zone 1. The ZCR trend since 2004 is shown in Figure 6.

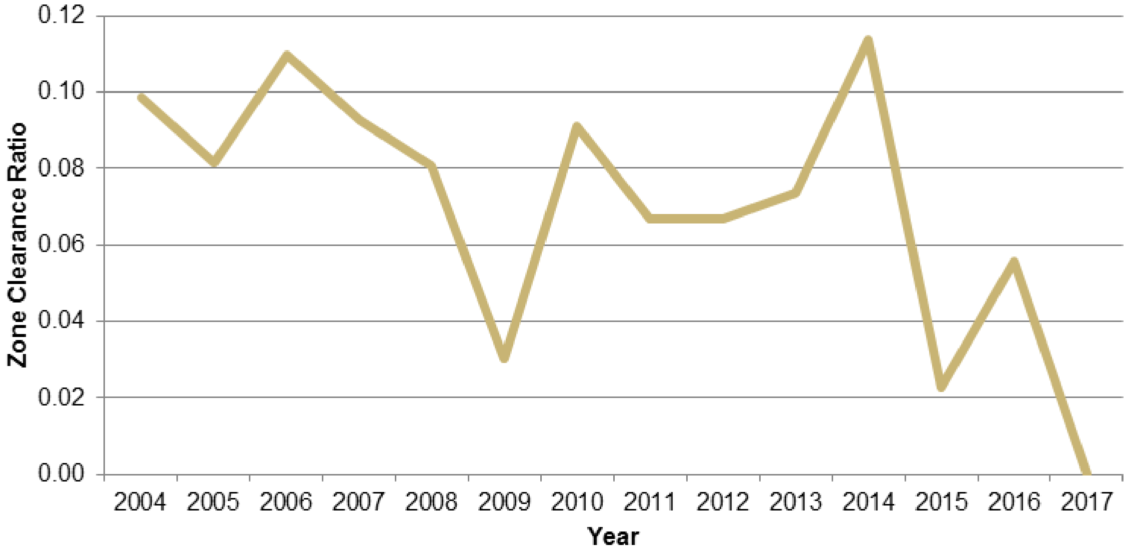


Figure 6: Zone clearance ratio 2004 - 2017: EirGrid

There were 56 system faults cleared by protection on the main system. This figure is made up of 55 faults on the main system and one fault outside the main system.

4.5.1 Frequency Control

In 2017 the system frequency was operated between 49.9 Hz to 50.1 Hz for 99.6% of the time.

This figure of 99.6% exceeds the 2017 target of 94%.

4.6 Summary of key disturbances

Loss of Load

T08/2017: Ikerrin

At 15:36 hours on Wednesday 01 March 2017, the Ikerrin - Shannonbridge - Thurles 110 kV line tripped and reclosed for a single phase to ground fault (SE). The fault was caused by lightning. 20.03 MW of load fed from Ikerrin was disconnected for the fault deadtime of approximately 574 ms. 0.000036 system minutes were lost due to the fault.

T22/2017: Kilkenny

At 14:02 hours on Monday 19 June 2017, the Kellis - Kilkenny 110 kV line tripped for a single phase to ground fault (RE). The fault was caused by contact with vegetation. Kilkenny 110 kV station was tail from Kellis at the time of the fault due to an outage of the Great Island - Kilkenny 110 kV line. Supply was interrupted to Kilkenny 110 kV station for 27 minutes. 36.5 MW of load fed from was fed from Kilkenny prior to the fault, resulting in the loss of 0.181471 system minutes.

T24/2017: Somerset

At 01:08 hours on Tuesday 18 July 2017, the Cashla - Shannonbridge - Somerset 110 kV line tripped and reclosed for a three phase fault. The fault was caused by lightning. 8.44 MW of load fed from Somerset was disconnected for the fault deadtime of approximately 526 ms. 0.000014 system minutes were lost due to the fault.

T45/2017: Dallow

At 00:51 hours on Sunday 01 October 2017, the Dallow - Portlaoise - Shannonbridge 110 kV line tripped and reclosed for a single phase to ground fault (RE). The cause of the fault is unknown. 6.1 MW of load fed from Dallow was disconnected for the fault deadtime of approximately 696 ms. 0.000013 system minutes were lost due to the fault.

Under Frequency Load Shedding

T42/2017: CCGT trip

At 13:00 hours on Sunday 24 September 2017, a CCGT in the North tripped from 393 MW eight seconds after a CCGT in the South had unexpectedly reduced its output from 400 MW to 78 MW. System frequency dropped from 50.033 Hz to 49.309 Hz at nadir. Frequency was below 49.8 Hz for 6 minutes 50 seconds. The STAR scheme was activated during this incident, which resulted in the disconnection of 8.5 MW of transmission connected interruptible industrial customer load for 8 minutes 22 seconds. 0.013462 STAR system minutes were lost. The system minutes lost during this disturbance relate entirely to STAR customers.

T61/2017: CCGT trip

At 17:02 hours on Monday 27 November 2017, a CCGT tripped from 425 MW. System frequency dropped from 49.976 Hz to 49.249 Hz at nadir. Frequency was below 49.8 Hz for 11 seconds. The STAR scheme was activated during this incident, which resulted in the disconnection of 31.0 MW of transmission connected interruptible industrial customer load for 1 minute 50 seconds. 0.010772 STAR system minutes were lost. The system minutes lost during this disturbance relate entirely to STAR customers.

Storms

T06/2017: Storm Doris

Between 03:21 and 05:54 hours on Thursday 23 February 2017, there were 17 single phase to ground faults on the transmission system in the West and North West during Storm Doris. The faults were caused by wind. A level orange weather warning was in place.

All transmission system faults were cleared by the lines' protection in zone 1. Clearance times were between 60 ms and 100 ms.

There was one non system fault during this period; T132 in Sliabh Bawn tripped in sympathy with a fault on the Arigna - Carrick on Shannon - Corderry 110 kV line.

Between 04:22 and 04:48 hours, there were four single phase to ground faults (TE) on the Arigna - Carrick on Shannon - Corderry 110 kV line. Supply was interrupted to Arigna 110 kV station for periods of less than one second to 7 hours. 1.86 MW of load fed from was fed from Arigna prior to the first fault, resulting in the loss of 0.118771 system minutes.

T49/2017: Storm Ophelia

Between 11:07 and 14:23 hours on Monday 16 October 2017, there were 16 system faults on the transmission system across the South during Storm Ophelia. The faults were caused by wind. A level red weather warning was in place for the country.

There were two non-system faults during this period; the Kilbarry - Knockraha 2 110 kV line and Butlerstown - Killoteran 110 kV line tripped in sympathy with other faults.

Two 110/38 kV load transformers tripped for faults on the distribution system.

All transmission system faults were cleared by the lines' protection in zone 1. Clearance times were between 52 ms and 152 ms for faults that originated on the main system.

There were no supply interruptions due to faults on the main system.

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 7 shows the percentage Transmission System Unavailability in each month for 2017.

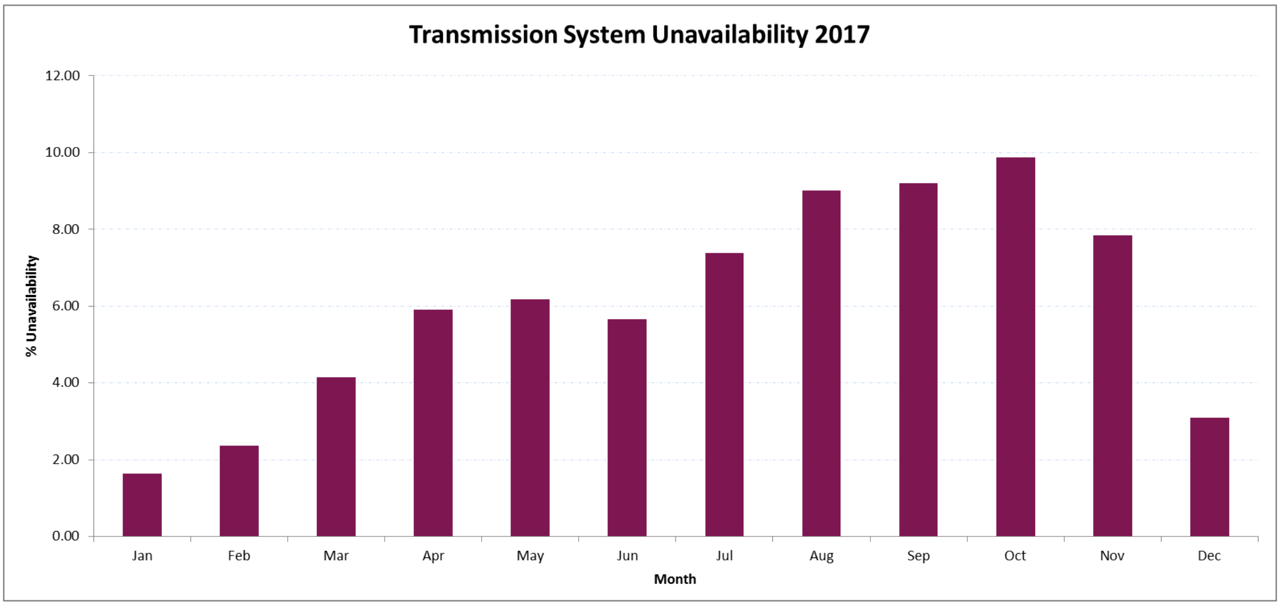


Figure 7: Monthly Variations of System Unavailability 2017

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 8 provides a detailed breakdown of all plant availability figures for 2017.

Table 8: Transmission System Plant Availability 2017

Plant Type	Circuit Length [km]	Number of Outages	Availability (%) 2017
110 kV Circuits	4345	461	93.51
220 kV Circuits	1934	111	96.99
275 kV Circuits	97	4	95.84
400 kV Circuits	439	8	86.64
Plant Type	**Transformer Capacity [MVA]**	**Number of Outages**	**Availability (%) 2017**
220 / 110 kV Transformers	10739	92	93.69
275 / 220 kV Transformers	1200	7	96.92
400 / 220 kV Transformers	4050	23	97.31
Total	6814 km 15989 MVA	706	94.56

In 2017:

•The average transmission system plant availability was 94.56%;

• The maximum availability by plant type was 97.31%, which occurred on the 400/220 kV transformers; and

• The minimum availability by plant type was 86.64%, 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 9.

Table 9: 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 8 provides a breakdown of the causes of unavailability on the 110 kV network in 2017.

The largest contributor to unavailability (43%) on the 110 kV network in 2017 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 Cauteen Killonan 110kV Line, which lasted 116 days. This was to facilitate the uprating of the line and carry out maintenance works.

A further 31% 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 Bellacorick Castlebar 110 kV line. The purpose of this outage was to uprate the line with new HTLS conductor.

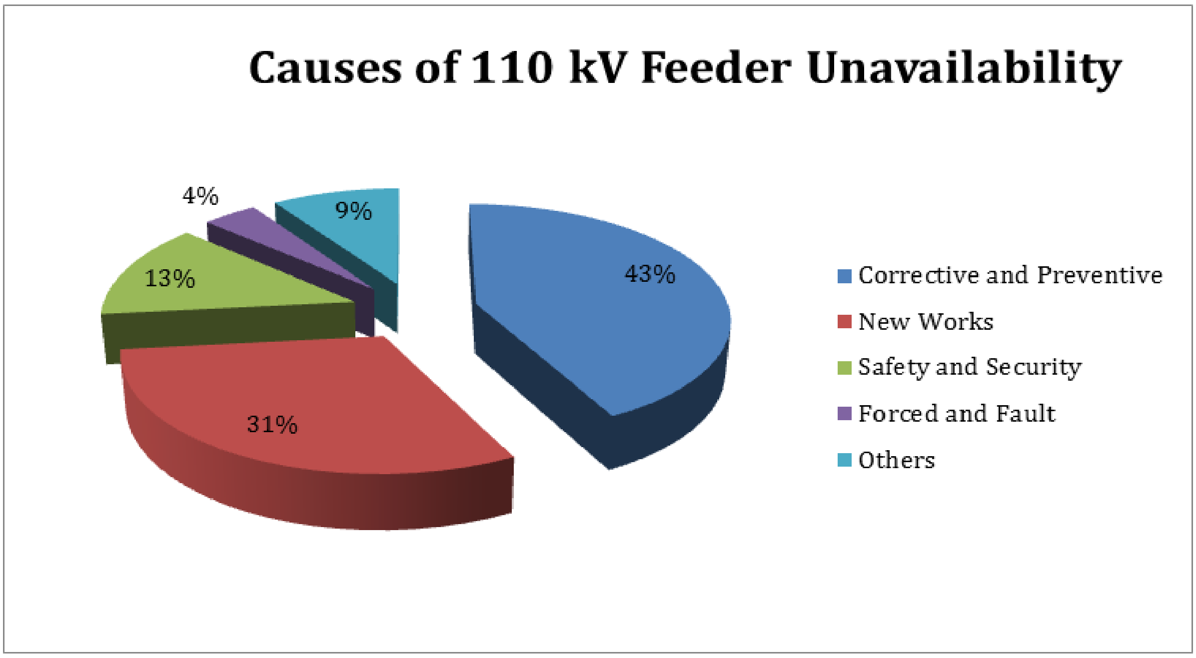


Figure 8: Causes of Unavailability on the 110kV System in 2017

4.7.5 220 kV Plant Unavailability

Figure 9 provides a breakdown of the causes of unavailability on the 220 kV network in 2017.

The largest contributor to unavailability (56%) on the 220 kV network in 2017 were outages for the purpose of corrective and preventative maintenance. The most significant of these was the outage of the Knockanure Tarbert 220kV circuit for 72 days. The purpose of this was for tower foundation reinforcements, HTLS conductor uprate and tower painting.

Approximately 16% of unavailability on the 220 kV network was attributable to New Works. The most significant of these outages was on the Corduff Woodland 1 (ONE) 220 kV line which lasted 74 days. The purpose of this was to upgrade protection for the Clonlee station tie-in.

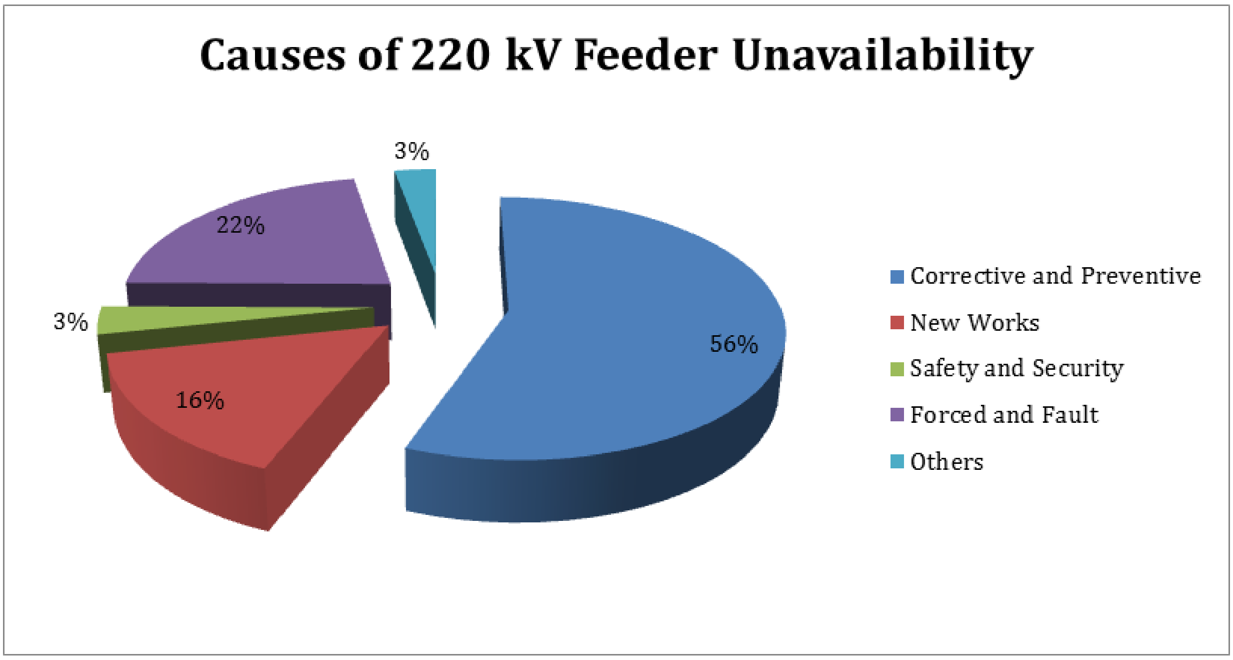


Figure 9: Causes of Unavailability on the 220kV System in 2017

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 2017 there were 4 outages of 275 kV tie-lines, two of which were for corrective and preventative maintenance. The most significant of these was an 18 day outage of Louth –Tandragee 2 (TWO) to facilitate maintenance.

4.7.7 400 kV Plant Unavailability

Figure 10 provides a breakdown of the causes of unavailability on the 400 kV network in 2017.

The largest contributor to unavailability (93%) on the 400 kV network in 2017 was new works. The most significant of these was the outage of the Dunstown Moneypoint 400 kV line. This 94 day outage was to facilitate the transfer of the 400kV line to the new 400kV GIS.

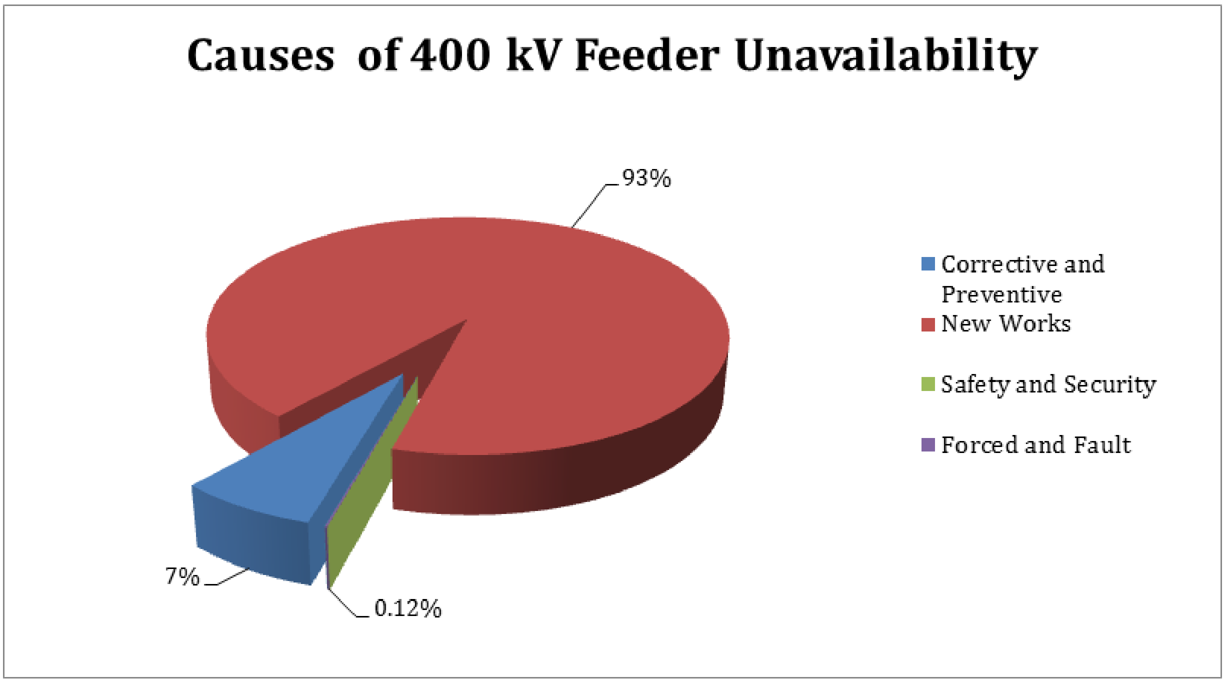


Figure 10: Causes of Unavailability on the 400kV System in 2017

Table 10 provides a breakdown of the transmission system outages that occurred in 2017 by plant type.

Table 10: Transmission System Plant Outage 2017

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	461	4345	22	41	84	236	78	461
220 kV Circuits	111	1934	4	18	16	53	20	111
275 kV Circuits	4	97	0	0	0	2	2	4
400 kV Circuits	8	439	2	0	1	4	1	8
Total	584	6814	28	59	101	295	101	584
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	10739	12	9	8	49	14	92
275 / 220 kV Trafos	3	1200	0	0	0	3	4	7
400 / 220 kV Trafos	8	4050	4	0	3	4	12	23
Total	65	15989	16	9	11	56	30	122

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 264km HV cable, 185km of which is submarine.

4.7.9. East West Interconnector Unavailability

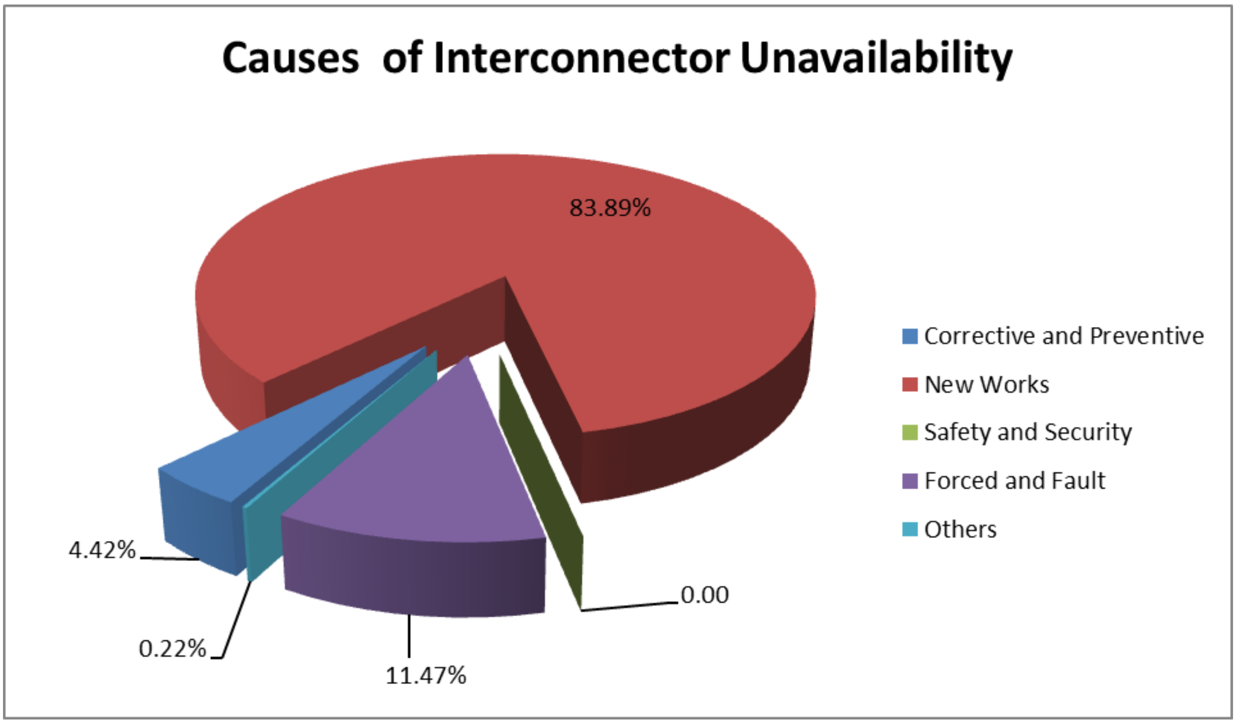


Figure 11: Causes of East West Interconnector Unavailability in 2017

In 2017 the availability of the East West Interconnector (EWIC) was 85%.

Of the outages contributing to EWIC unavailability, new works represented the largest portion of unavailability at 83.89%. This was due to a major project undertaken in May 2017 to transfer the connection point in Great Britain from Deeside 400KV AIS station to the new Connahs Quay 400kV GIS station.

Forced and Fault was the second largest cause of unavailability at 11.47% due to a forced outage of EWIC lasting 6 days. 4.42% of the unavailability was due to corrective and preventive maintenance; this does not include a portion of maintenance works (25 days) which was carried out during the new works outage. 0.22% of the unavailability was due to 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.

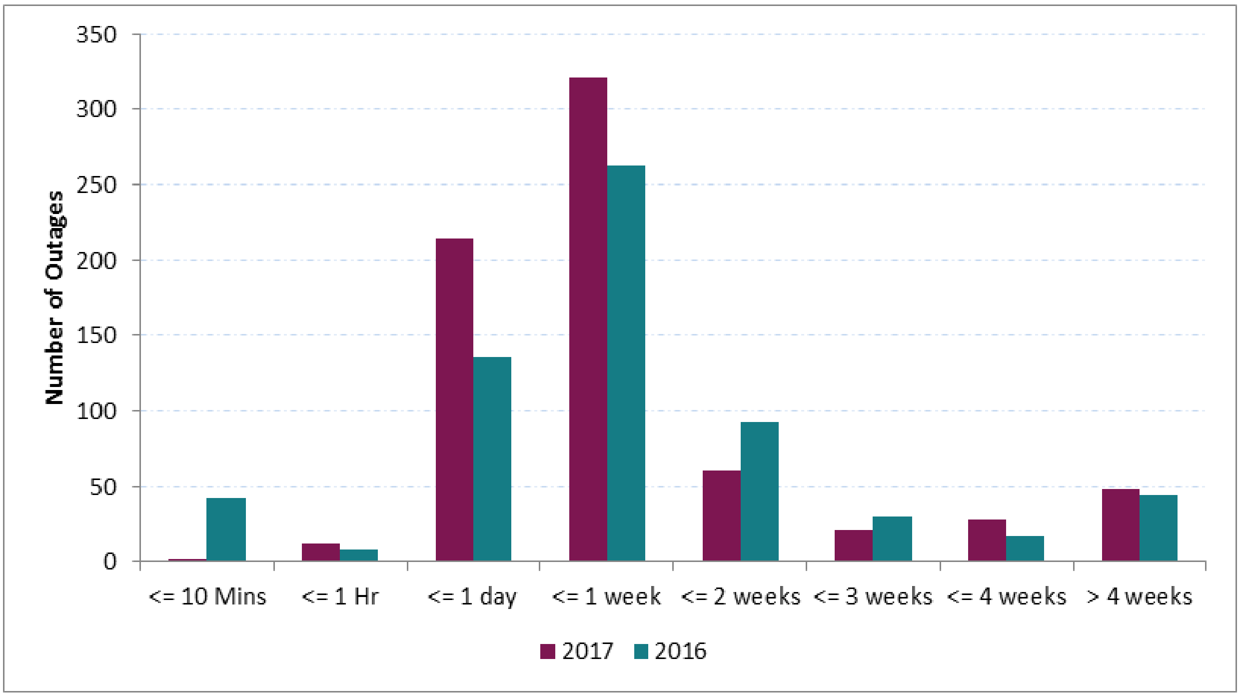


Figure 12: Duration of Outages in 2016 & 2017

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-October 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 78 day outage of Great Island-Waterford 1 (ONE) to carry out Corrective and Preventative Maintenance. Figure 14 shows the average duration in days of the transmission outages in each month in 2017.

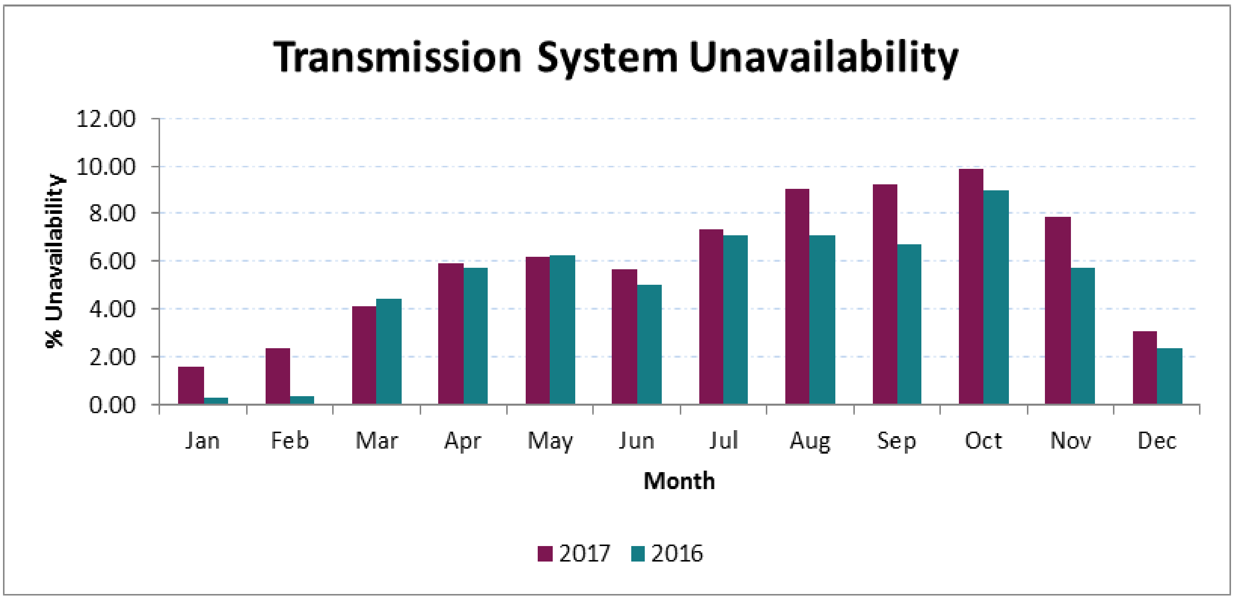


Figure 13: Percentage unavailability in each month of 2016 & 2017

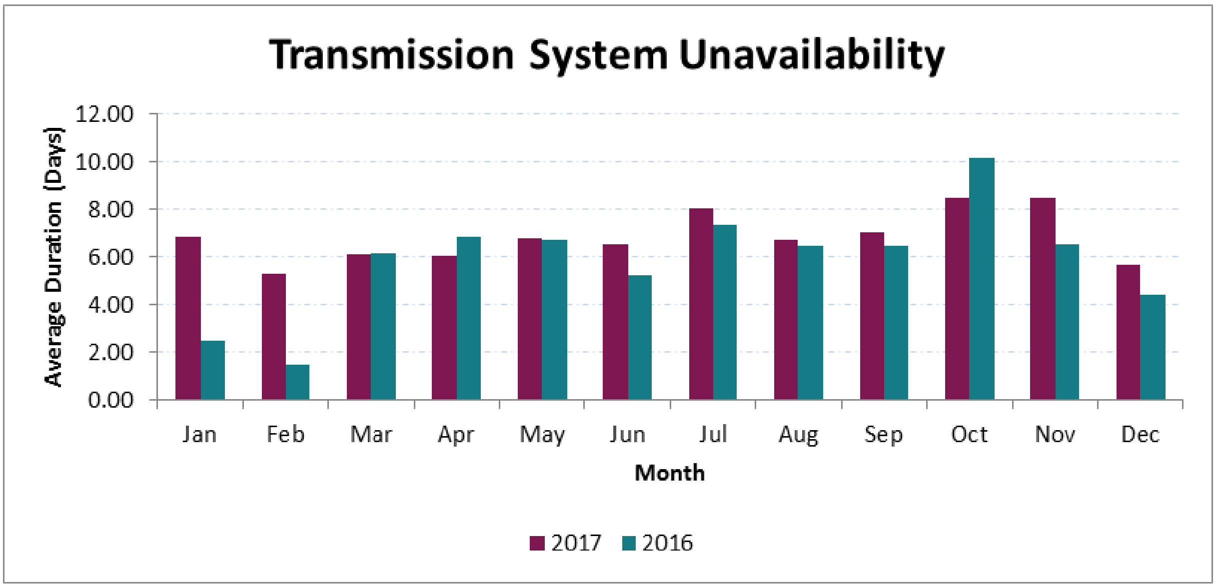


Figure 14: Average duration of outages 2016 & 2017

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.

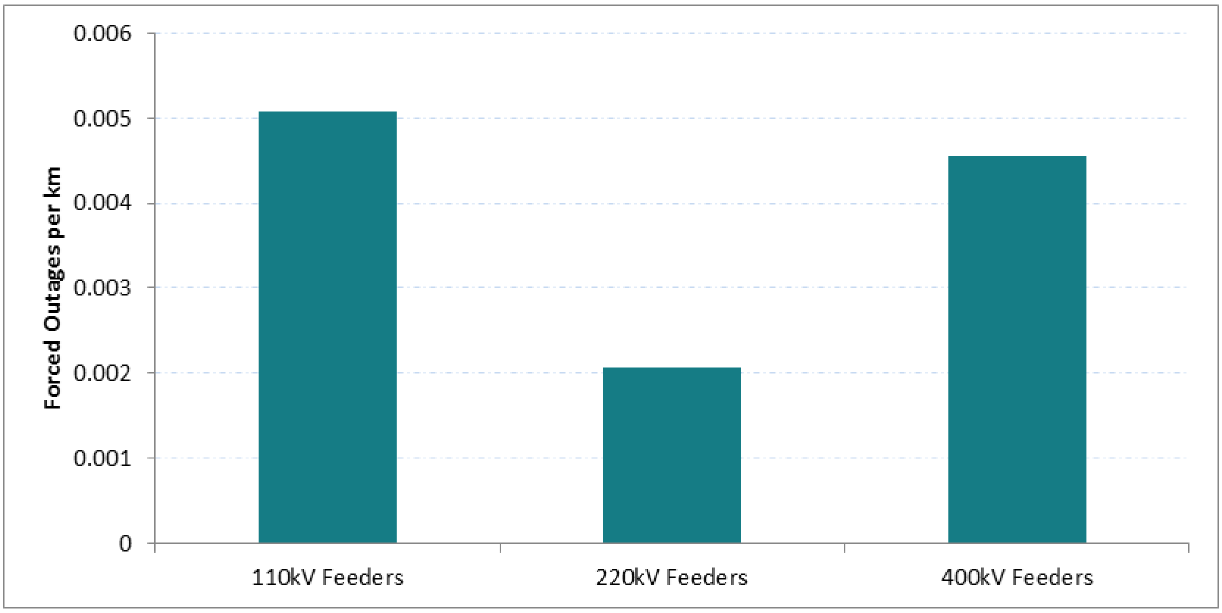


Figure 15: Forced Outages of lines and cables in 2017

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.

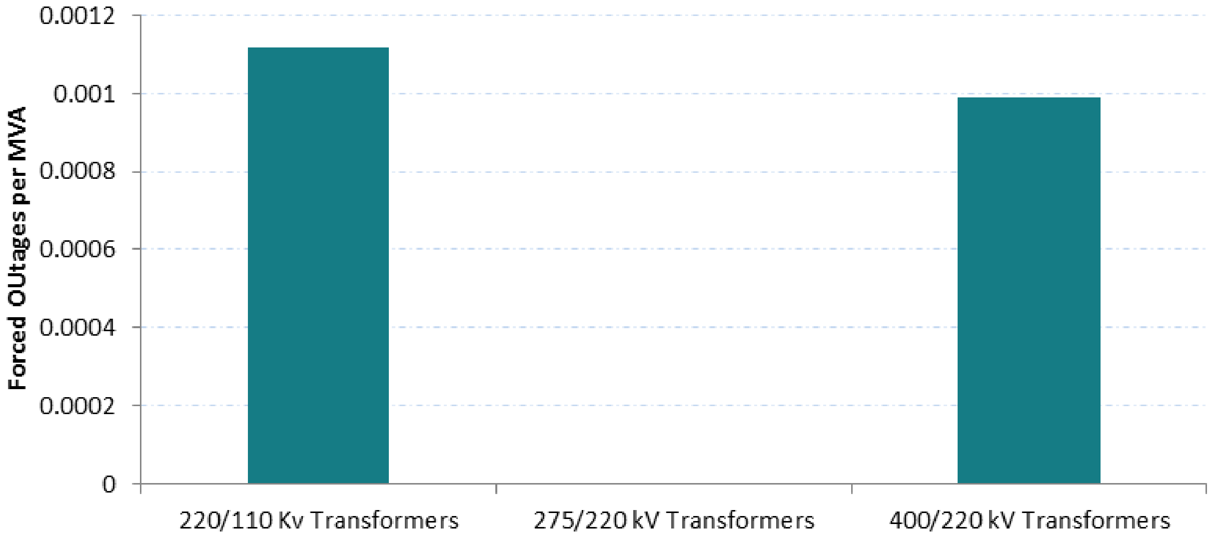


Figure 16: Transformer Forced Outages in 2017

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 2130 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 2017 was 96.30%. Ongoing project work was completed in 2017 which consisted of refurbishment work at 110 kV substations across Northern Ireland. A new build 110 kV substation at Brockaghboy was commissioned in 2017 to facilitate the connection of renewable energy to the Northern Ireland network.

The annual availability of the Moyle Interconnector for 2017 was 69.69%. A subsea cable fault was the cause of the reduced interconnector availability. A repair of this fault was completed in 2017.

The North-South 275 kV tie line, connecting Louth in Ireland and Tandragee in Northern Ireland, had an availability of 96% in 2017. The annual availability of the two 110kV tie lines was 93% and 100% in 2017.

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 2017, there were four transmission incidents leading to customers being off supply. These were;

- On the 27th of February at 15:24, an incident at Hannahstown substation resulted in the loss of supply to 27826 customers. The system minutes lost for this event was 0.288.
- On the 12th of May at 01:59, an incident at Belfast North Main substation resulted in the loss of supply to 32567 customers. The system minutes lost for this event was 0.481.
- On the 23rd of July at 09:42, the Tamnamore – Creagh 110kV line tripped resulting in the loss of supply to 12350 customers. The system minutes lost for this event was 0.221.
- On the 22nd of August at 23:29, Kells – Antrim A and B 110kV lines tripped due to lightning resulting in the loss of supply to 23672 customers. The system minutes lost for this event was 1.143.

Quality of service is measured by the number of voltage and frequency excursions which fall outside statutory limits. There were no voltage excursions in 2017 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 2017, there were 34 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:

Equation 1: System Availability Formula

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

In 2017, the analysis of the transmission system availability data has produced the following results:

- The average availability of the Northern Ireland transmission system was in 2017 was 96.30%,
- The average winter system availability (for the winter months January, February, November and December 2017) was 97.77%.

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

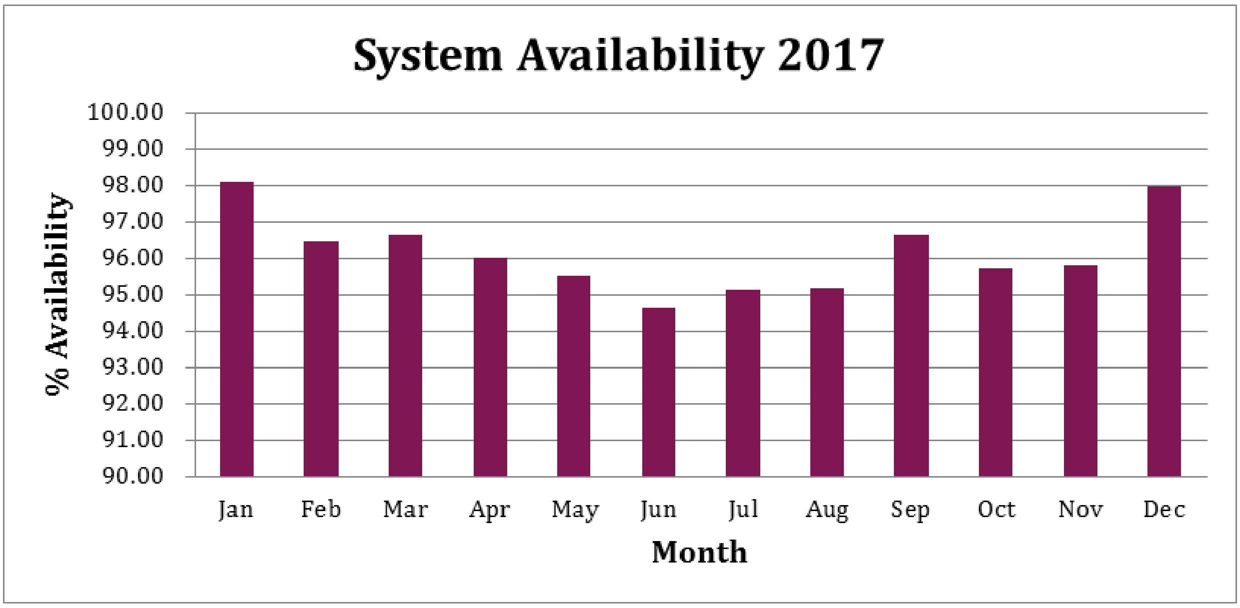


Figure 17: Transmission System Availability 2017

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.

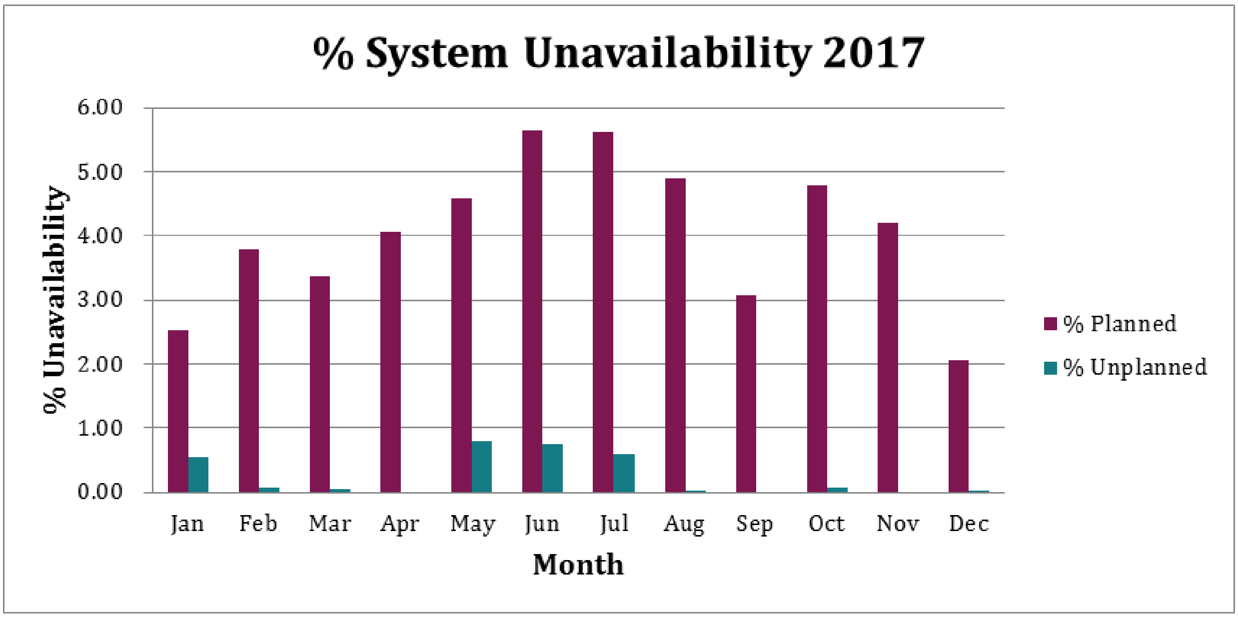


Figure 18: Transmission System Unavailability 2017

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 1999 to 2017 for the transmission network in Northern Ireland.

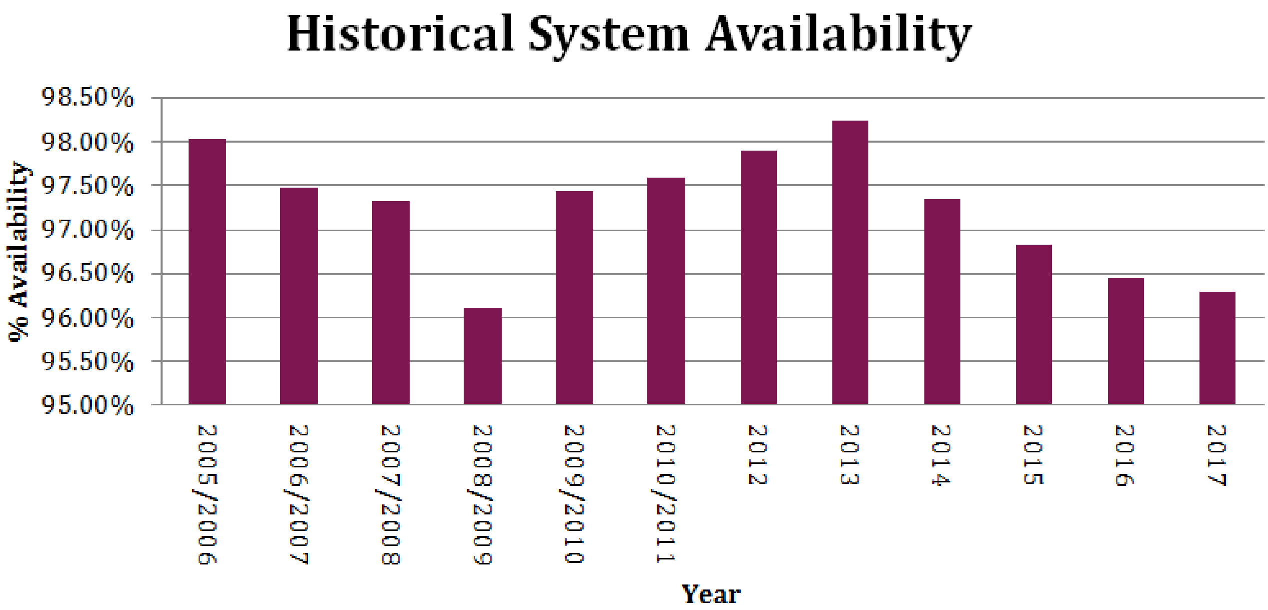
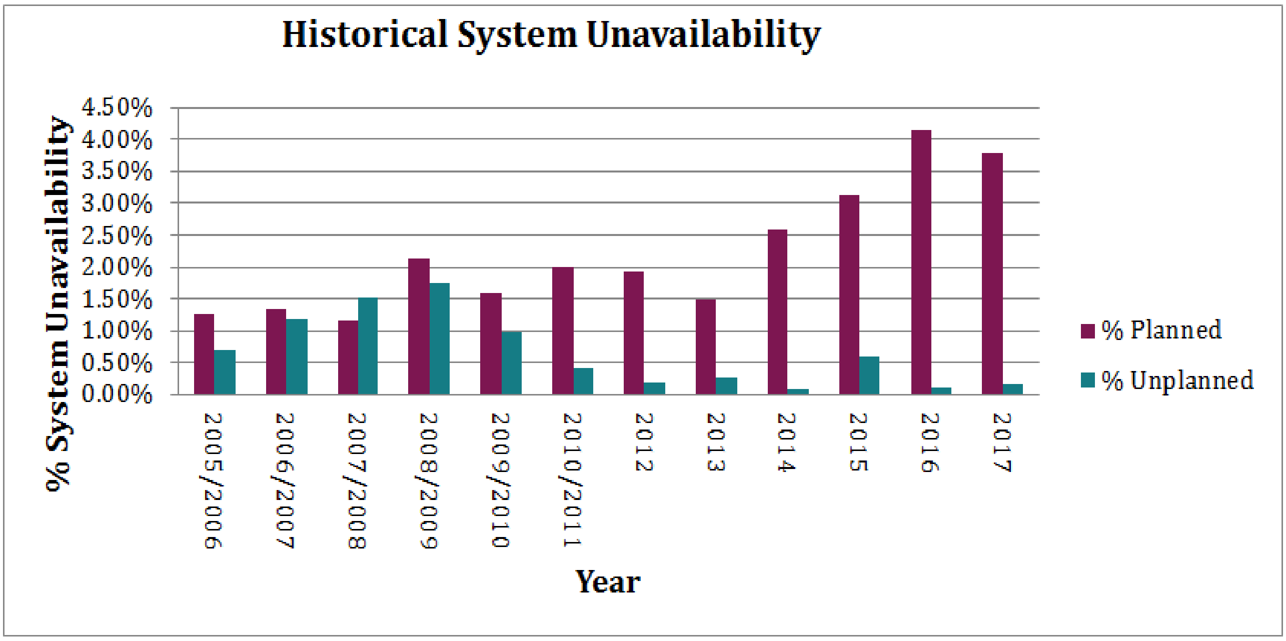


Figure 19: Historical System Availability 1998-2017[6]

5.2.4 System Historical Unavailability Performance

Figure 20 below shows the breakdown of the system unavailability from 1999/2000 to 2017.



[3] Prior to 2012, SONI calculated system availability in line with the company's financial year. This practice ended in 2012, in line with the practice in EirGrid.

Figure 20: Historical System Unavailability 2005-2017

There has been a drop in system unavailability in 2017 compared to 2016, shown in Figure 20 above. In 2017, as part of the price control RP5, NIE Networks has continued its commitment to upgrade existing infrastructure as well as constructing new assets to meet the ongoing changes of the power system. Examples of this include:

- New cluster substation at Brockaghboy.
- 110kV substation refurbishment work at Dungannon and Ballyvallagh.
- Protection upgrade on the 275kV overhead line between Kilroot and Tandragee.

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

In 2017, the Moyle interconnector sustained a cable fault on the south of Pole 1. An outage of approximately seven months was required to repair this outage. During this outage, the interconnector had a restricted maximum import and export capacity of 250MW. Other outages throughout the year consisted of small technical faults and regular maintenance.

5.2.6 Moyle Interconnector Historical Availability

The Annual Availability of the Moyle Interconnector for 2017 was 69.69%.

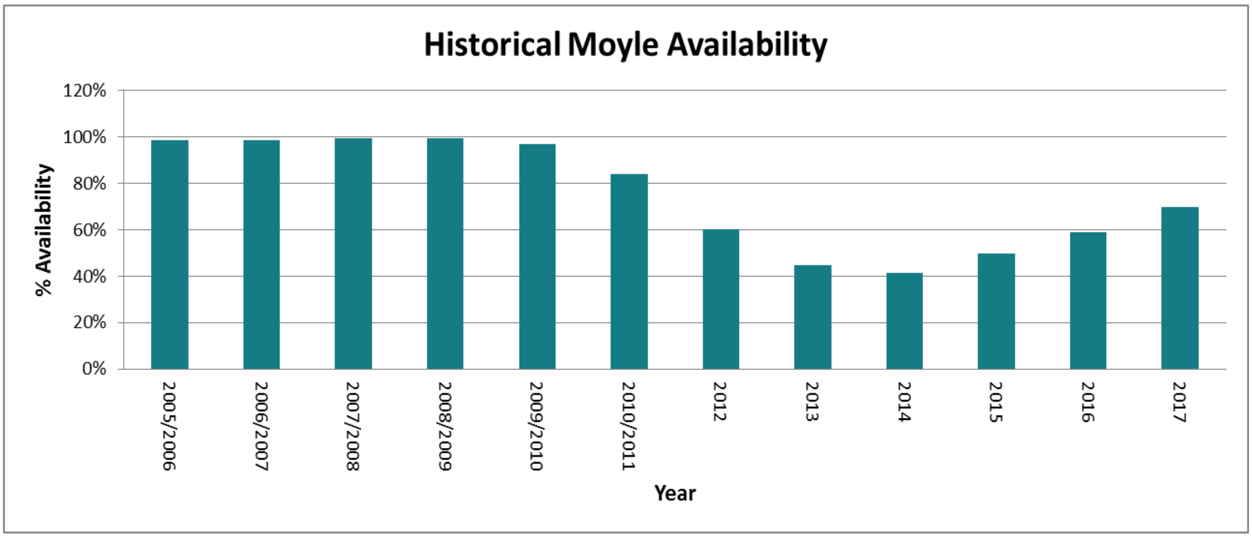


Figure 21: Historical Moyle Interconnector Availability 2002/03 - 2017

5.2.7 Moyle Interconnector Historical Unavailability

The 2017 Annual Unavailability of the Moyle Interconnector was 30.31%.

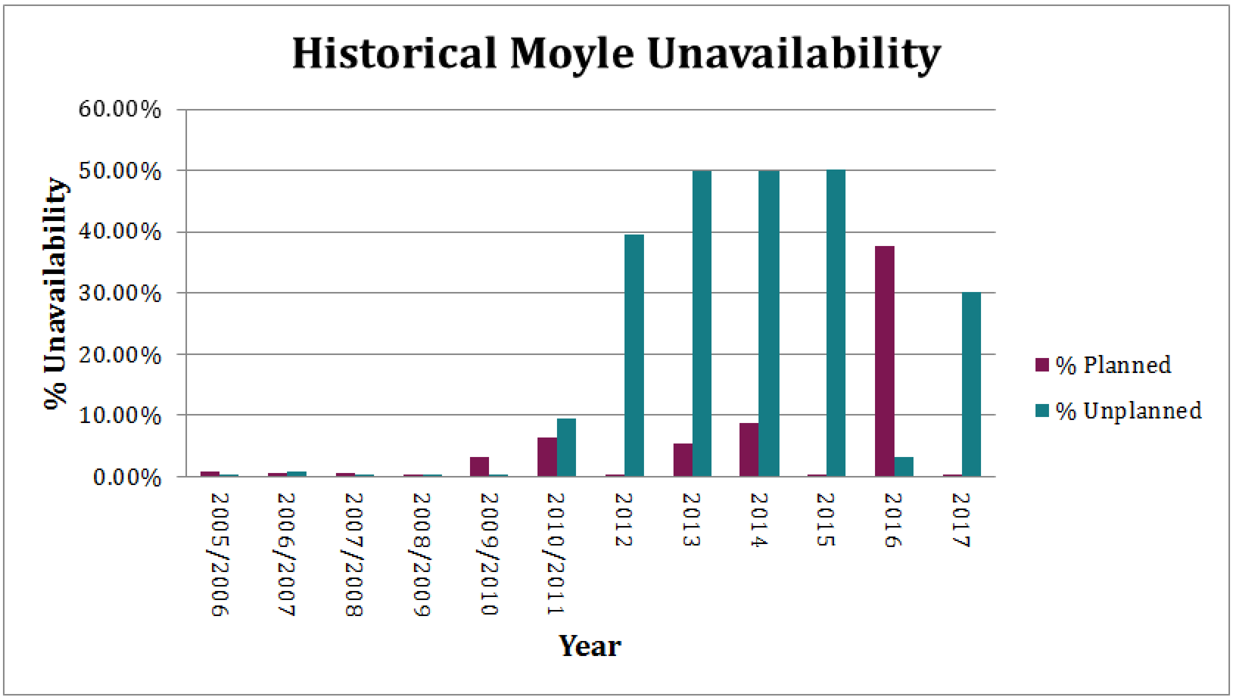


Figure 22: Historical Moyle Interconnector Unavailability 2005-2017

5.2.8 Moyle Interconnector Monthly Unavailability

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

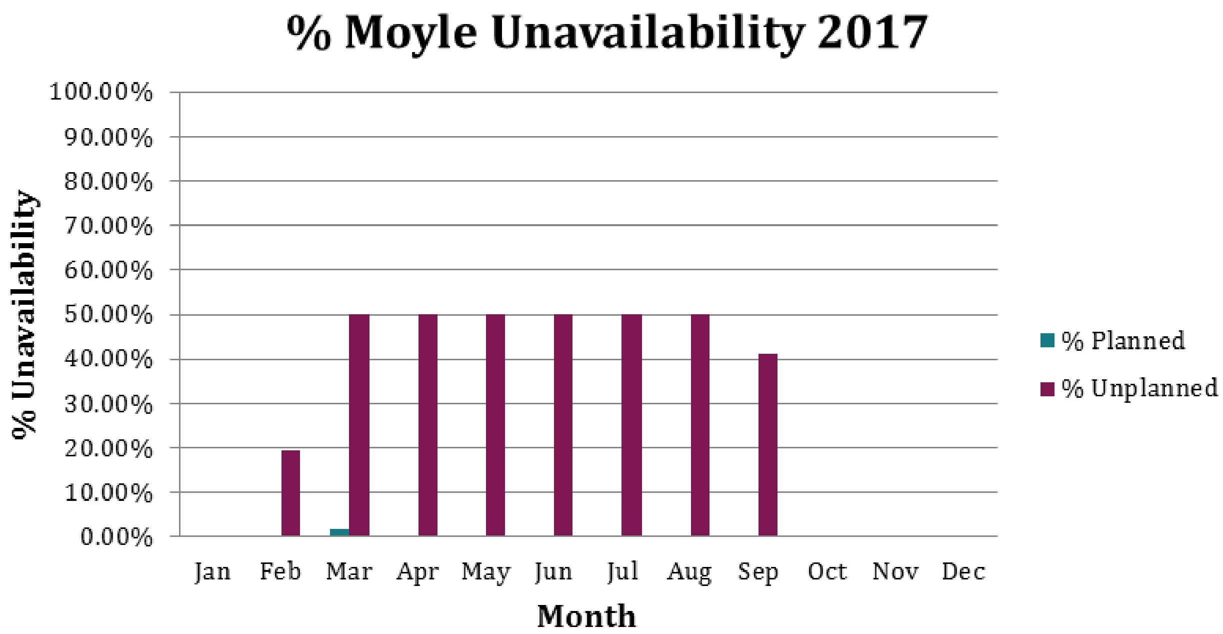


Figure 23: Moyle Interconnector Unavailability 2017

Figure 23 shows approximately seven months where the interconnector only had half its capacity available in 2017. This was due to a cable fault on one of the poles obtained in February, which wasn't fully repaired until late September. During this period, the interconnector's maximum import and export capacity was 250MW.

Other outages in 2017 consisted of resolving minor technical problems and regular maintenance work, often lasting a short period of time.

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 275kV North-South Tie Line in 2017 was 96.10%.

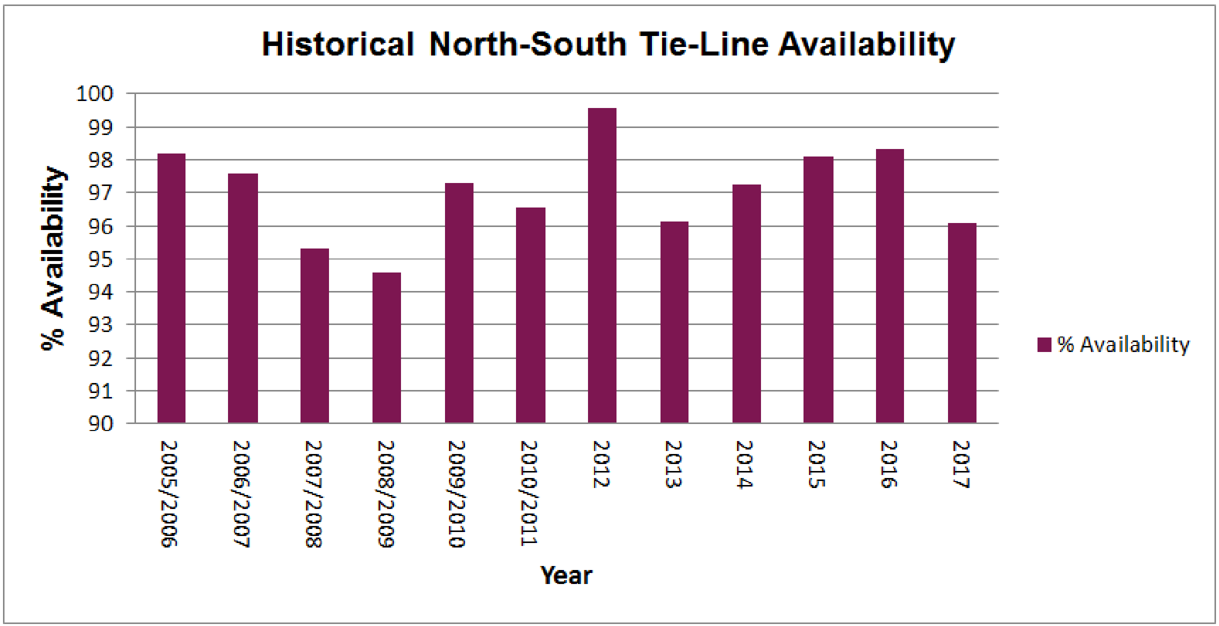


Figure 24: Historical North-South Tie Line Availability 1995-2017

5.2.10 110kV 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 PST's 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 96.73% in 2017.

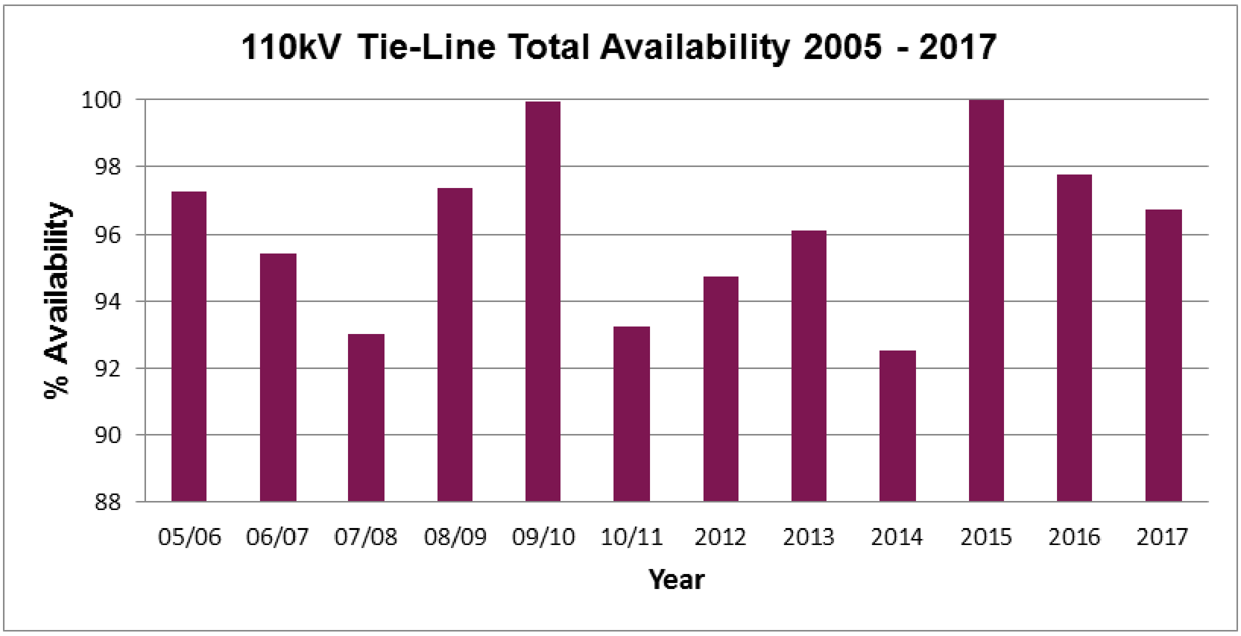


Figure 25: North-South Tie Line Availability 2005-2017

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

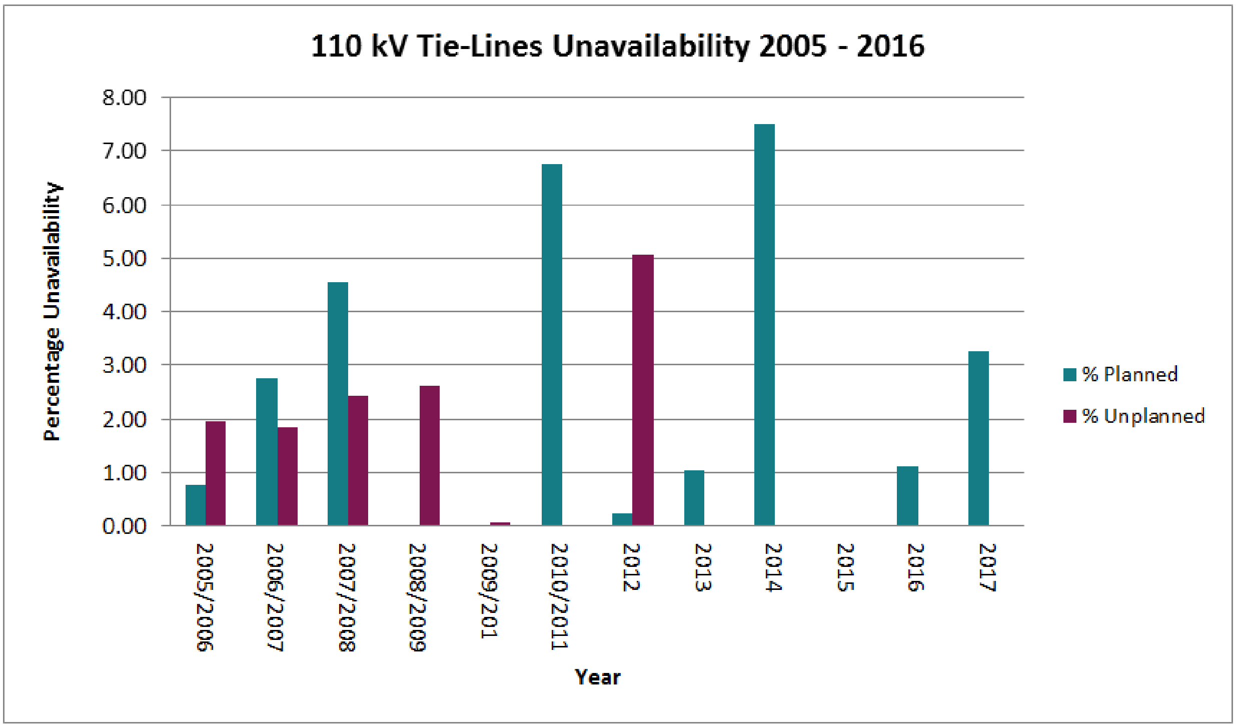


Figure 26: Historical 110kV Tie Line Unavailability 2005-2017

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 2017

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 2017, there were four system events in Northern Ireland that resulted in the loss of supply to customers. Details of these events are given below.

- On the 27th of February, an event occurred at Hannahstown substation that resulted in the loss of supply to 27,826 customers, equating to a total loss of 35 MW. All customers were fully restored within 14 minutes of the event happening.
- On the 12th of May, an event occurred at Belfast North Main substation that resulted in the loss of supply to 32,657 customers, equating to a total loss of 19 MW. All customers were fully restored within 43 minutes of the event happening.
- On the 23rd of July, the Tamnamore – Creagh 110kV line tripped resulting in the loss of supply to 12,350 customers, equating to a total loss of 11 MW. All customers were fully restored within 90 minutes of the event happening.
- On the 22nd of August, Kells – Antrim A and B 110kV lines tripped due to lightning resulting in the loss of supply to 23,672 customers, equating to a total loss of 26 MW. All customers were fully restored within 77 minutes of the event happening.

5.3.3 Incident Analysis

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

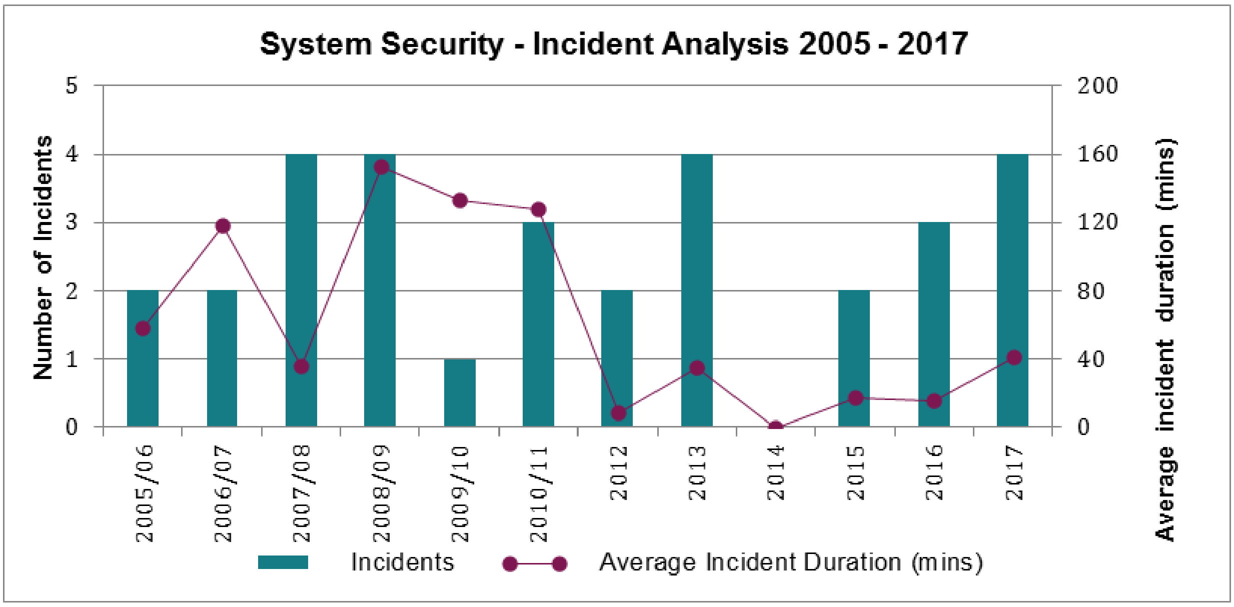


Figure 27: Historical System Security 2005-2017

5.3.4 Unsupplied Energy

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

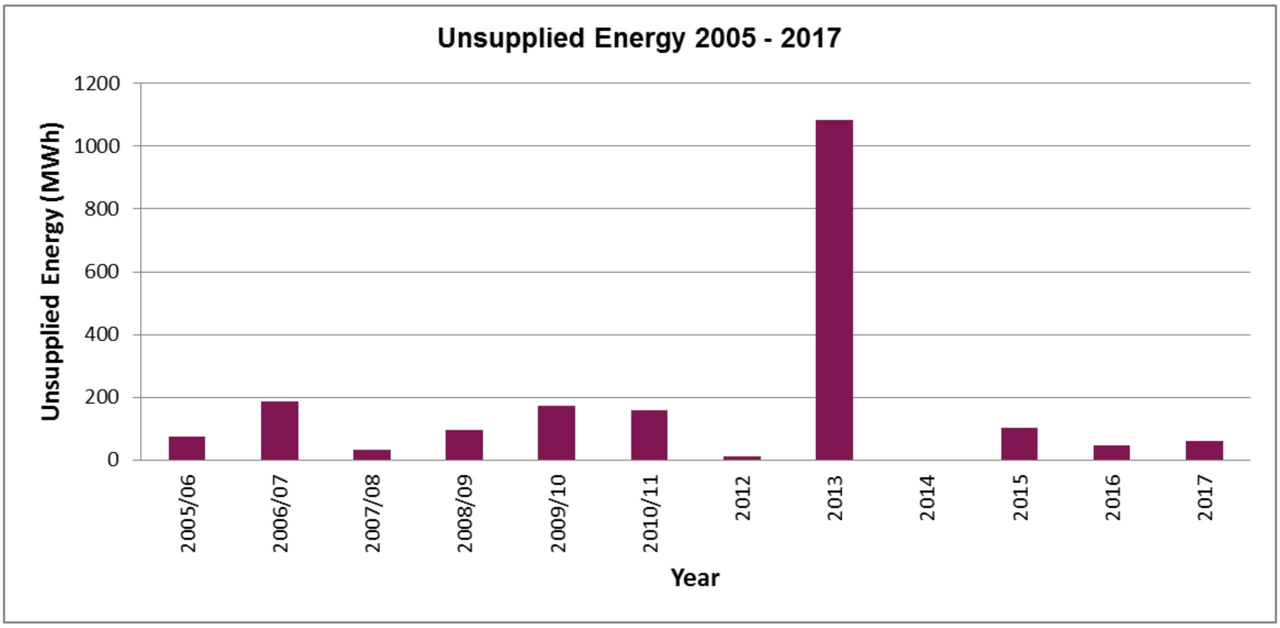


Figure 28: Historical Unsupplied Energy 2005-2017

5.3.5 System minutes lost

The total system minutes lost for 2017, attributable to SONI, was 2.133. The trend of system minutes lost since 2012 is shown in Figure 29.

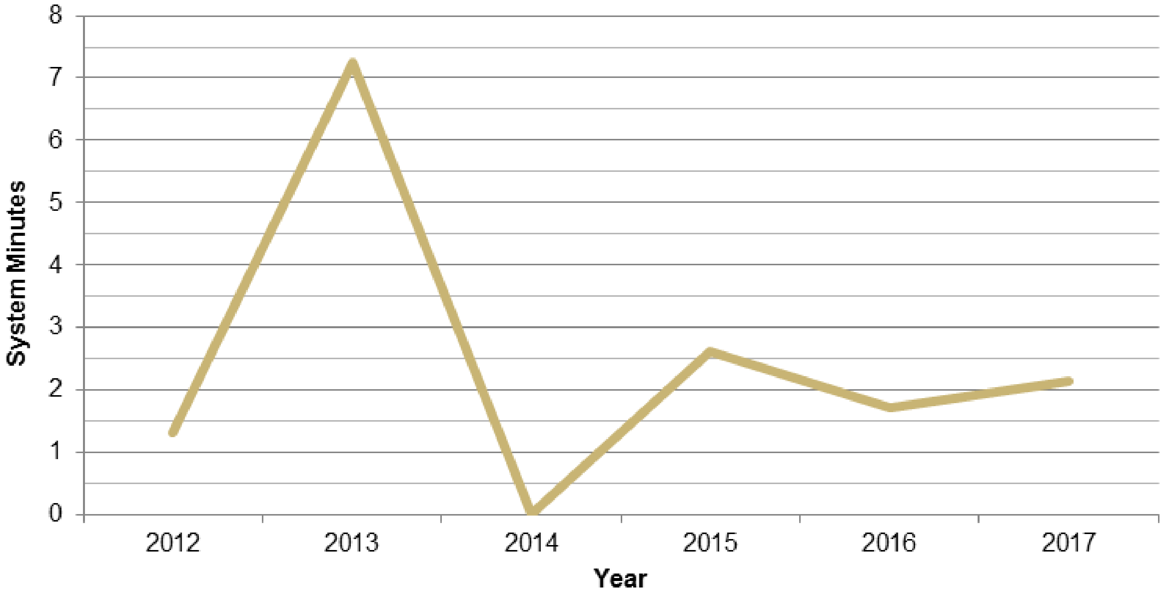


Figure 29: System minutes lost 2012 - 2017: SONI

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 2017, the ZCR was 0.200. There were 10 system faults cleared by protection on the main system; nine faults occurred on the main system and one outside the main system. Of the 10 faults, eight were cleared in zone 1, and two in zone 2. On Tuesday 22 August 2017, the Antrim - Kells A and B 110 kV circuits tripped to clear simultaneous single phase to ground faults (RE) caused by a lightning strike on a double circuit tower carrying both lines. Both faults were zone 2 clearances; the clearance times were approximately 260 ms

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 11.

Table 11: 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 2017.

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 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 8 reportable frequency excursions in Northern Ireland in 2017. Graphs in Appendix 2 contain traces of system frequency as well as raw and averaged rate of change of frequency data.

[7] SONI Operating Security Standards

5.4.4 Frequency Excursions

Table 12: Frequency Excursions in 2017

Cause of Incident	Date	Time (UTC)	MW Lost	Pre-incident Frequency (Hz)	Nadir (Hz)	Min Frequency POR (Hz)	Rate of Change of Frequency		t<49.6 Hz seconds	t<49.5 Hz seconds	N-S Tie Line Flow MW
							Max df/dt Hz/Sec	Average df/dt Hz/Sec			
Moyle	21/03/2017	12:15:53	244	49.940	49.595	49.629	-0.55	-0.2	1.2	0	112
Huntstown Unit 2	24/05/2017	06:32:39	350	49.980	49.571	49.613	-0.26	-0.19	2.9	0	-34
Aghada AD2	20/06/2017	11:50:34	410	50.000	49.386	49.413	-0.42	-0.33	6.9	5	-46
Huntstown Unit 2	15/07/2017	17:08:13	350	49.950	49.381	49.402	-0.26	-0.23	6.7	4.7	-35
Whitegate WG1	08/09/2017	11:37:00	180	50.000	49.399	49.45	-0.42	-0.32	6.5	4.1	64
Aghada AD2	24/09/2017	11:59:48	370	50.020	49.305	49.622	-0.5	-0.2	201.5	66.6	-89
Great Island GI4	05/10/2017	05:27:49	215	49.990	49.369	49.396	-0.45	0.24	7.9	5.4	-62
Great Island GI4	27/11/2017	17:02:50	410	49.990	49.245	49.255	-0.58	-0.29	8.4	7	-125

Note NS and Interconnection flows, +VE represents an import to Northern Ireland

Definitions

Time 0 seconds	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 (Hz)	Minimum system frequency from t 0 to t + 6 minutes
Minimum Frequency POR (Hz)	Minimum frequency during POR period from t + 5 seconds to t + 15 seconds
Max df/dt Hz/Sec	Maximum negative rate of change of frequency during the period t – 5 seconds to t + 30 seconds. (This is calculated from a five point moving average with a sample rate of 100 milliseconds) Measured at Kilroot Power Station
Average df/dt Hz/Sec	This is the rate of change of frequency observed between two points in time. The first point being when the frequency passes through 49.8 Hz and the second when the frequency nadir is observed between t + 5 seconds and t + 15 seconds Measured at Kilroot Power Station

5.4.5 Historical Frequency Excursions

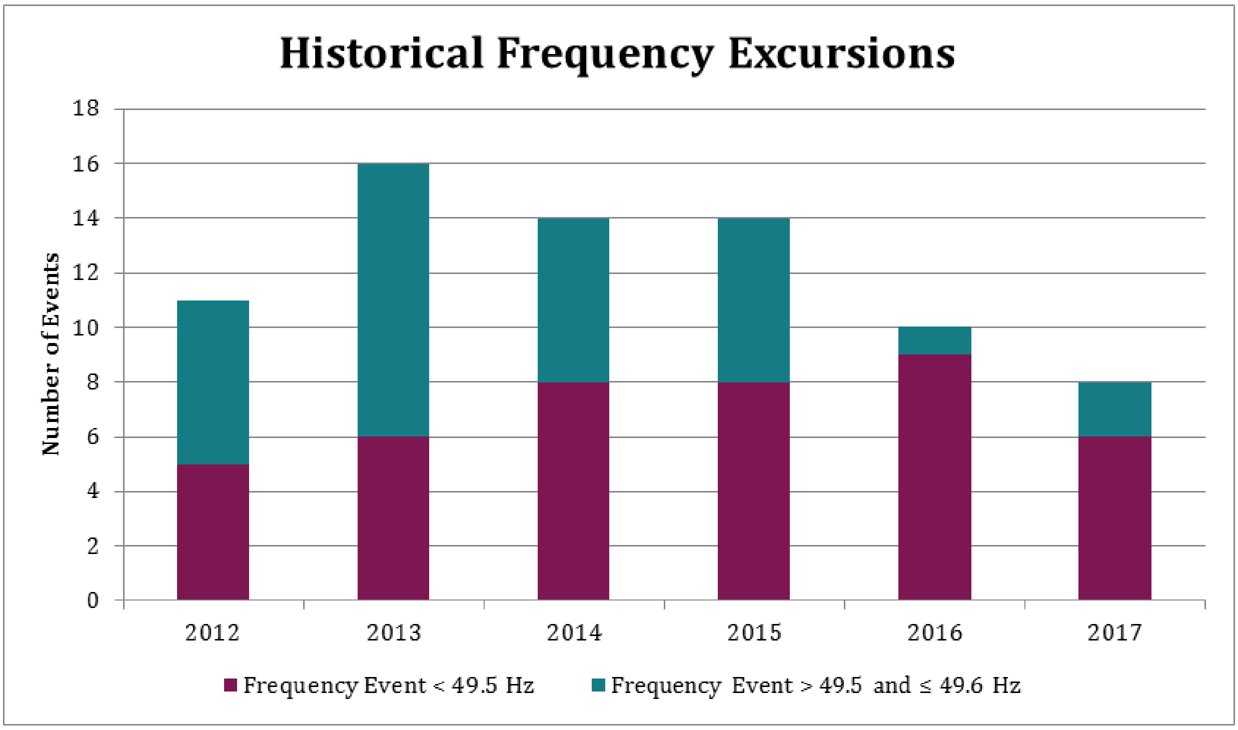


Figure 30: Historic Frequency Excursions 2012-2017

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 for the entire incident.

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

All HV plant on the Irish electricity network that does not form part of the Main System: The Dublin 110 kV network which is controlled by the DCC (the MV system in Ireland is controlled by the ESB 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: 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.

6.10 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

6.11 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.

6.12 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.

6.13 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.

6.14 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.

6.15 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.

6.16 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.

6.17 STAR Scheme

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

6.18 Sustained Interruption

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

6.19 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.

6.20 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

6.21 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.

6.22 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.

6.23 Zones of Protection

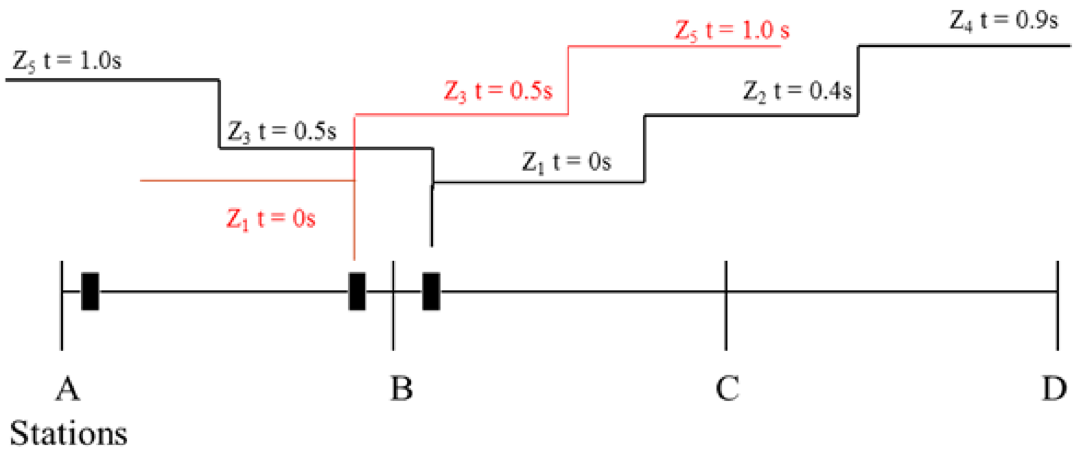


Figure 31: Zones of Protection

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.

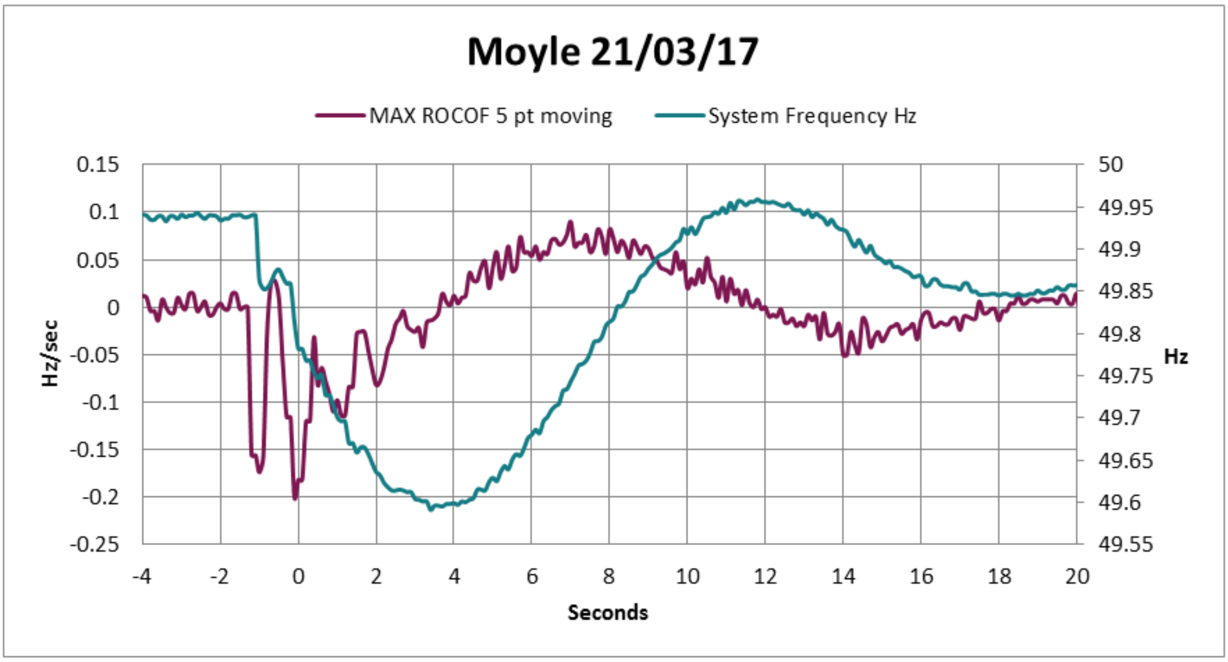
Zone 4 is the third forward step of a distance scheme with a time delay of approximately 900 ms.

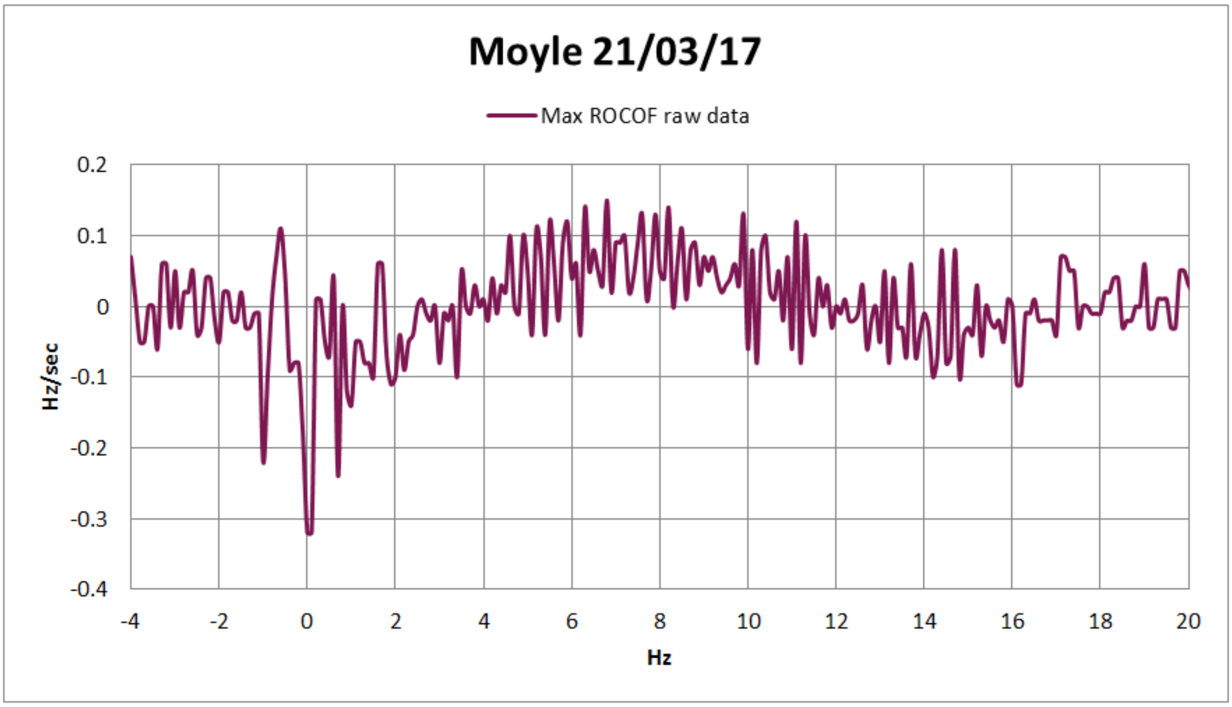
Zone 5 is the second reverse step of a distance protection scheme with a time delay of approximately 1.1 seconds.

7. Appendix 2 All Island Frequency Excursion Graphs

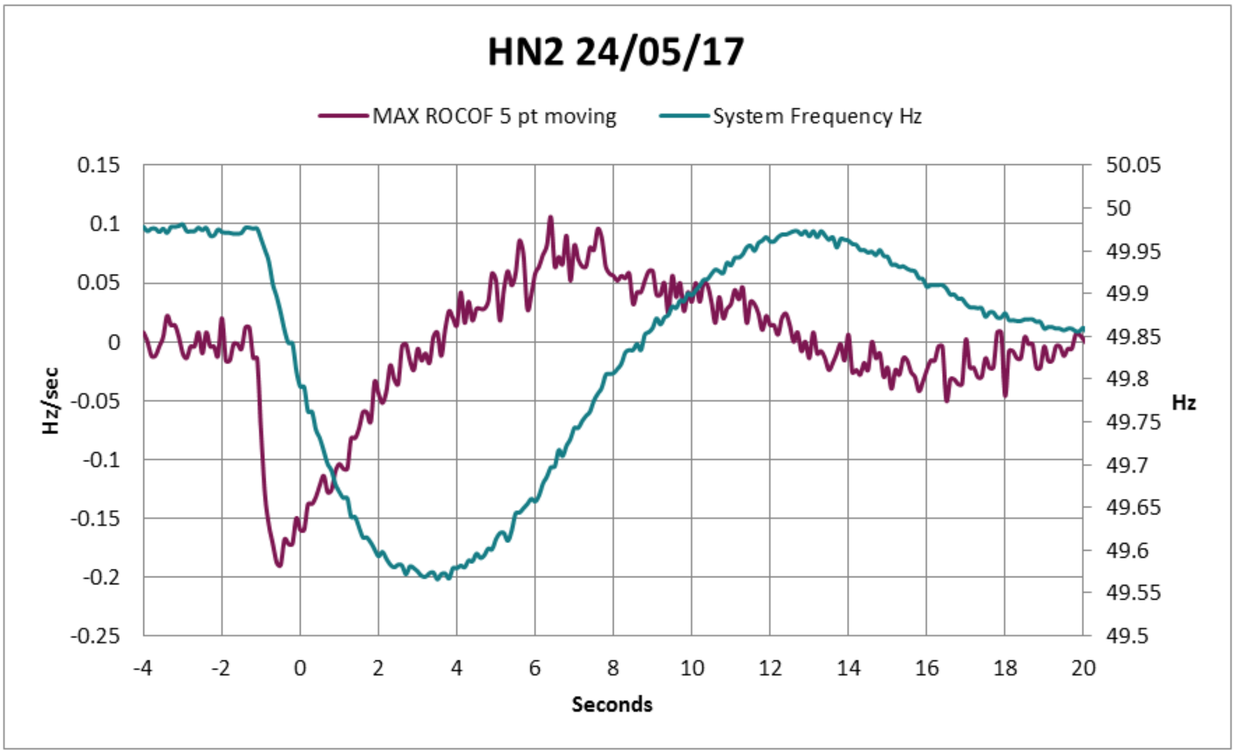
Cause of Incident	Date
Moyle	21/03/2017
Huntstown Unit 2	24/05/2017
Aghada AD2	20/06/2017
Huntstown Unit 2	15/07/2017
Whitegate WG1	08/09/2017
Aghada AD2	24/09/2017
Great Island GI4	05/10/2017
Great Island GI4	27/11/2017

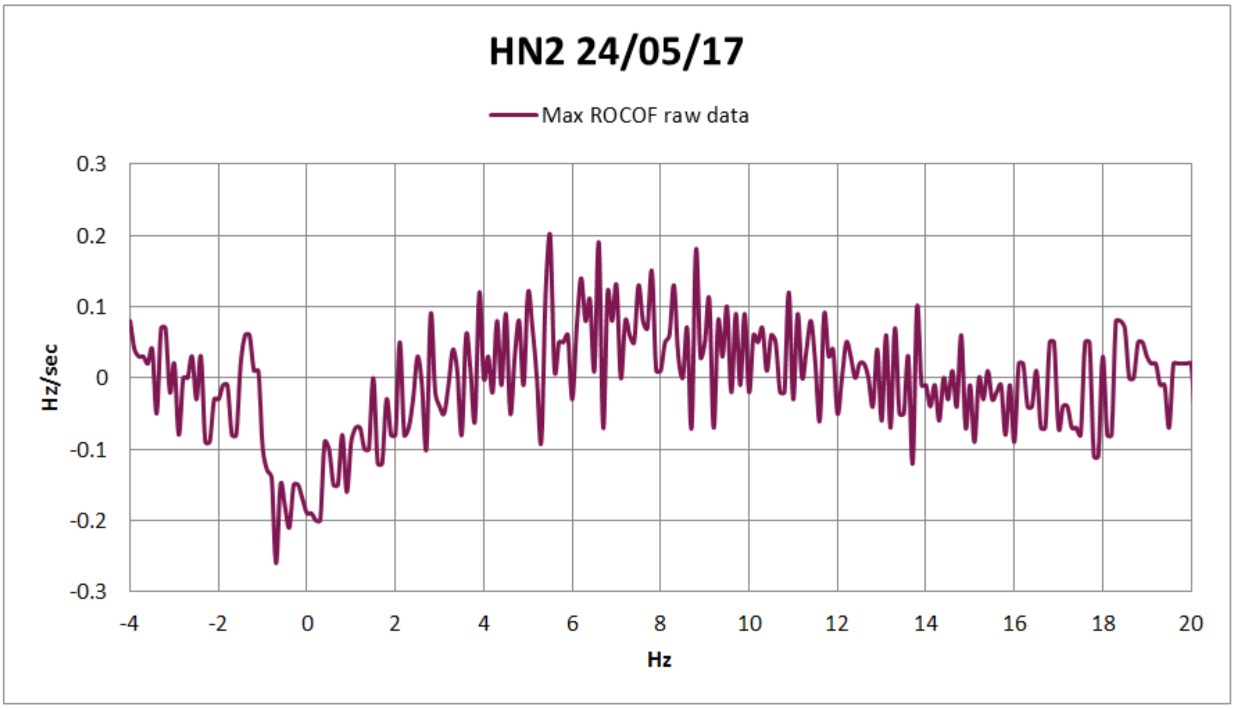
7.1 Moyle – 21/03/17



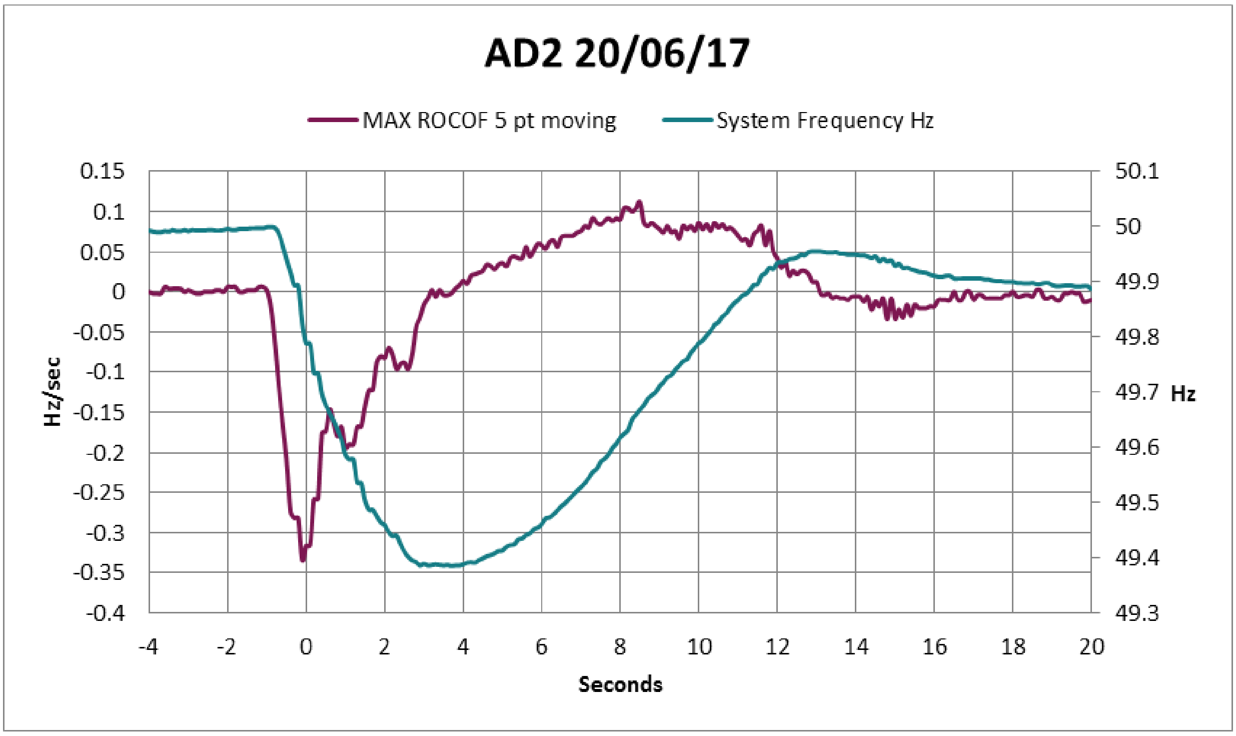


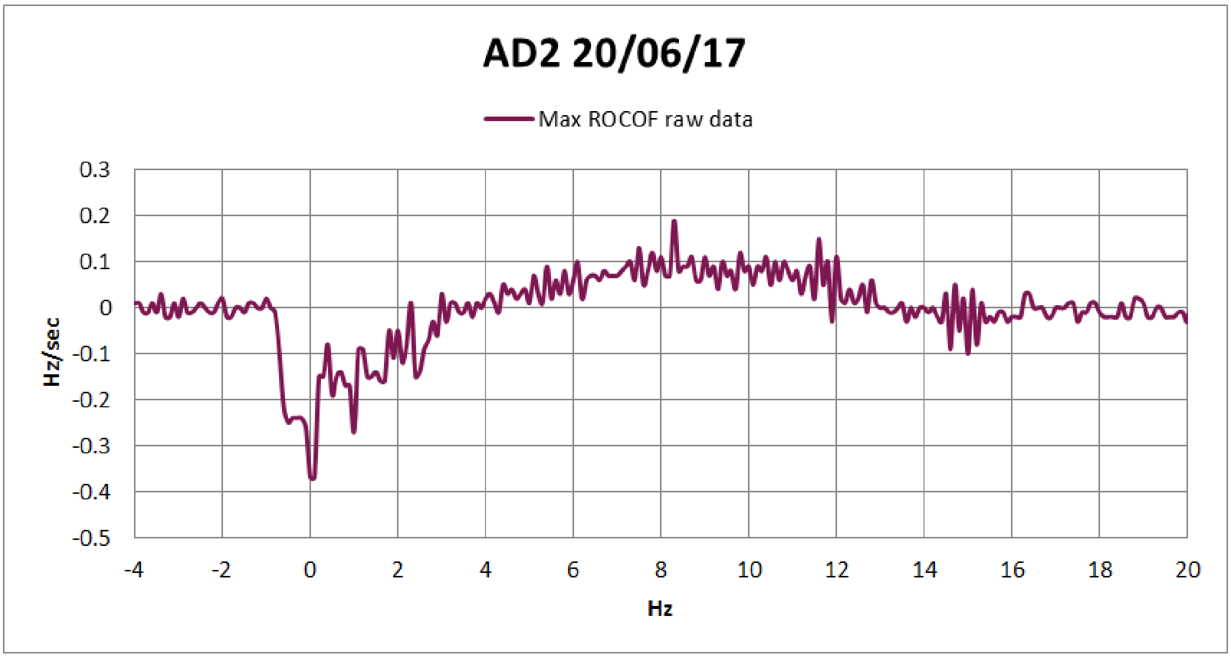
7.2 Huntstown Unit 2 – 24/05/17



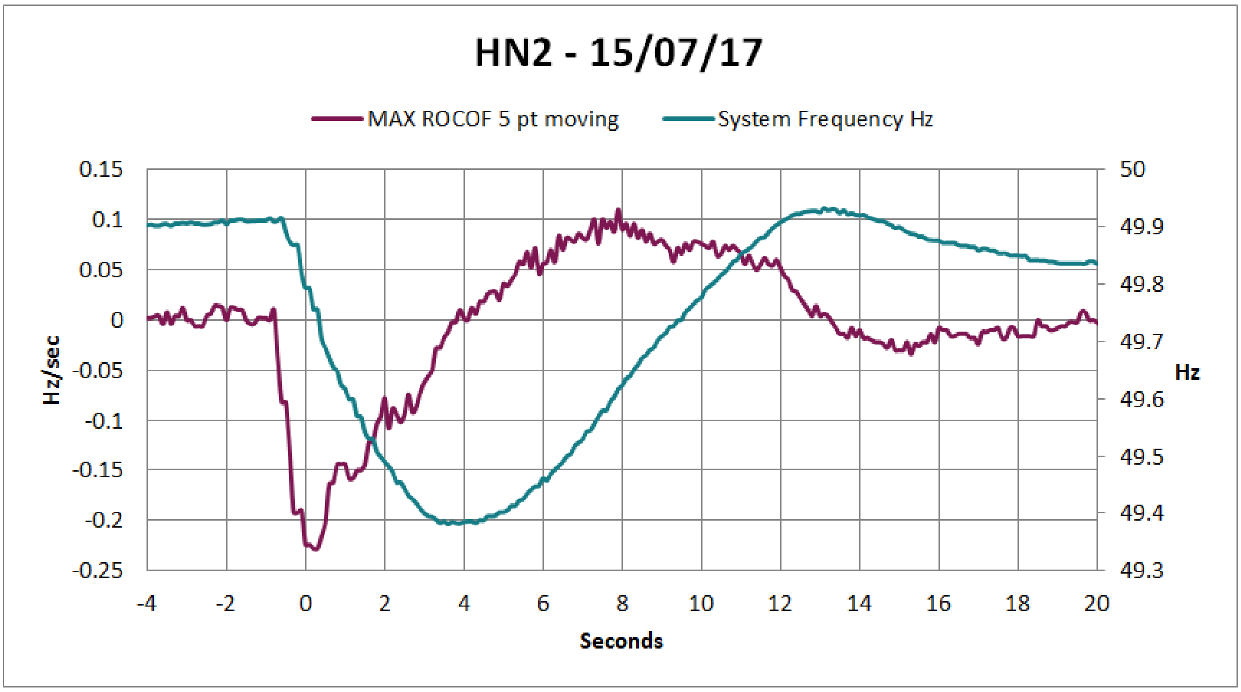


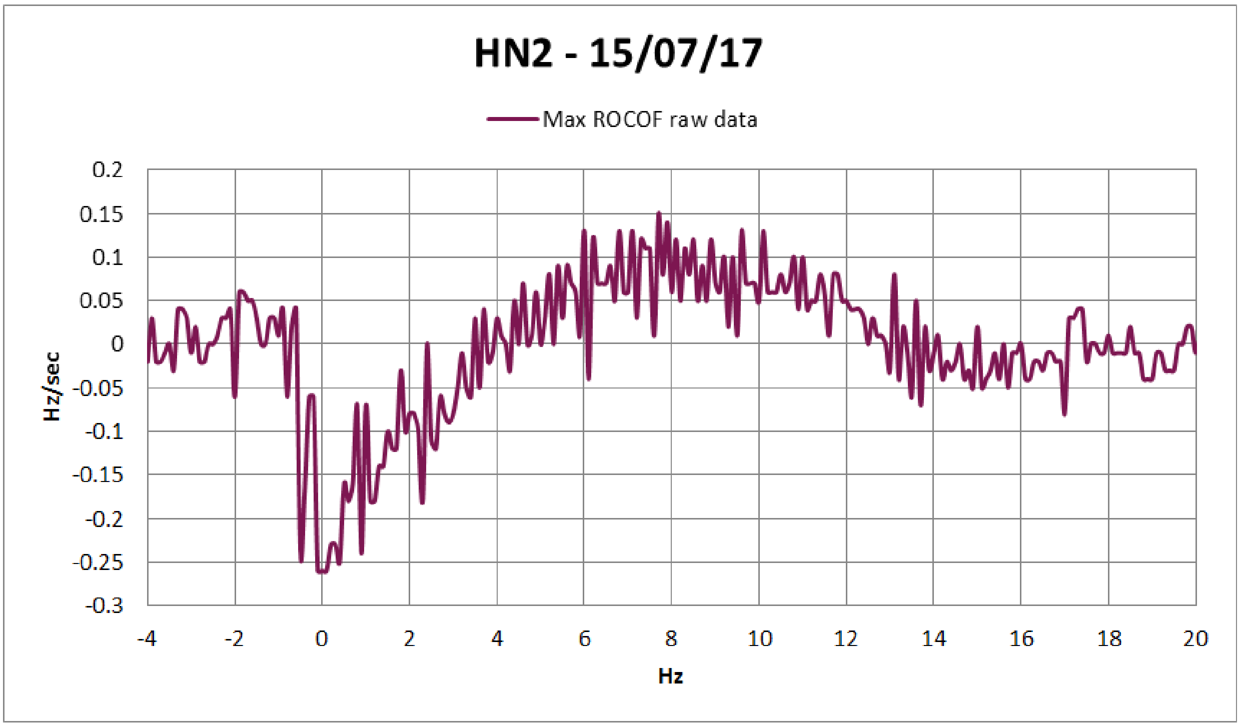
7.3 Aghada Unit 2 – 20/06/17



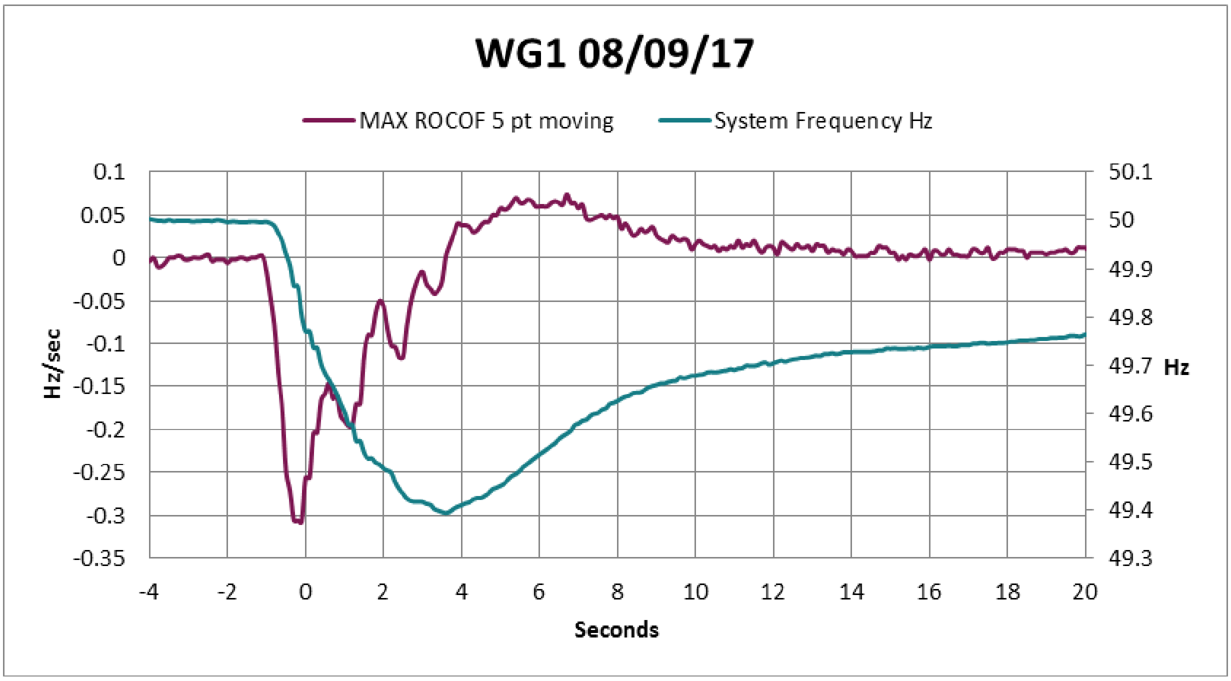


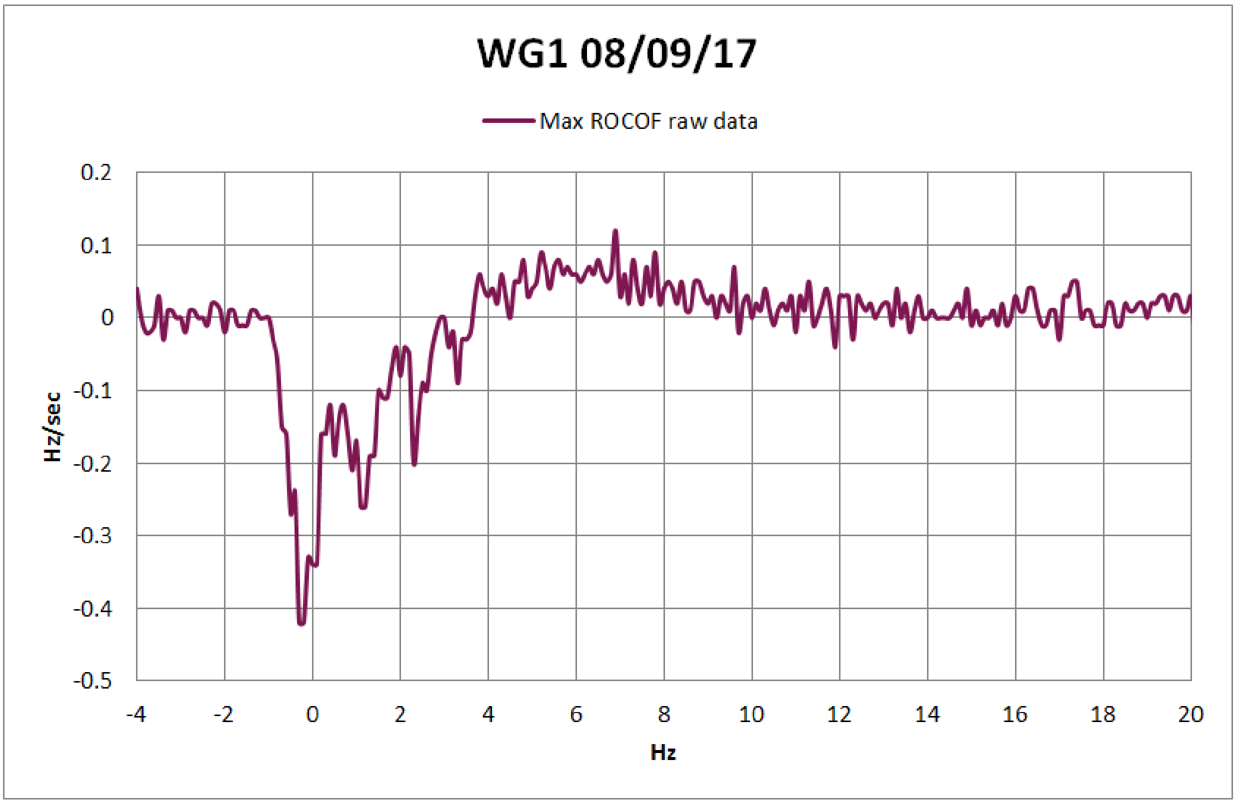
7.4 Huntstown Unit 2 – 15/07/17



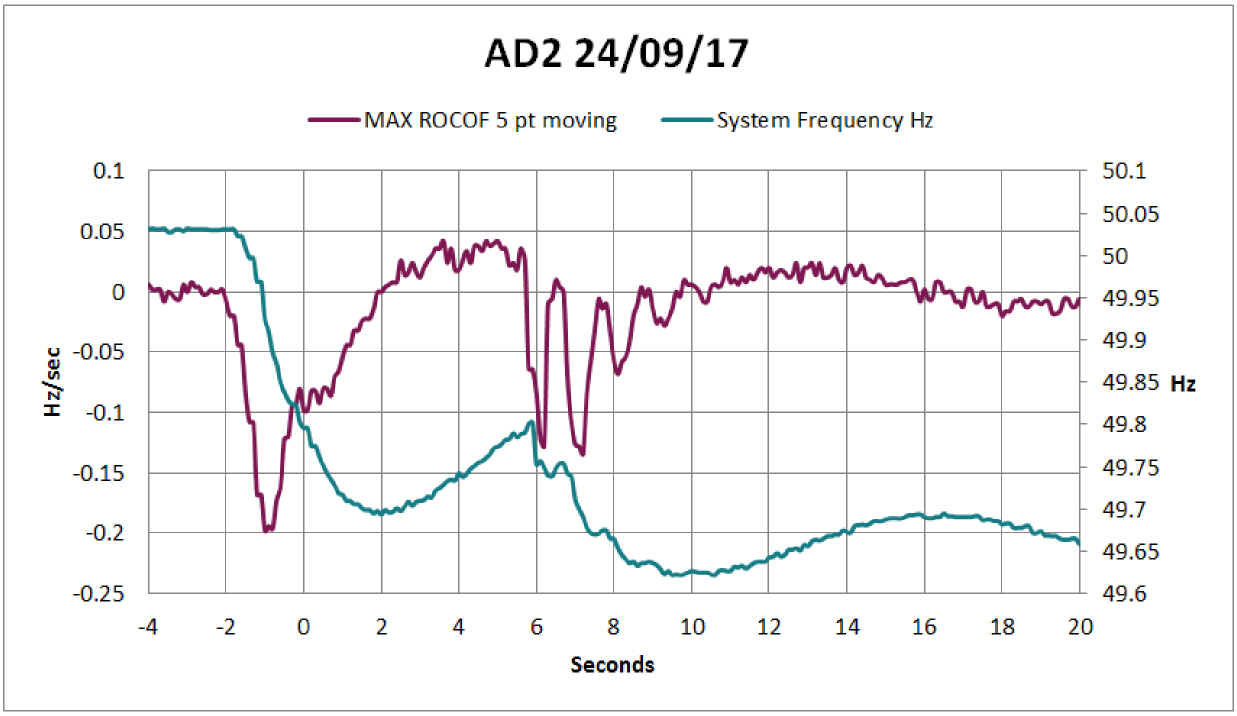


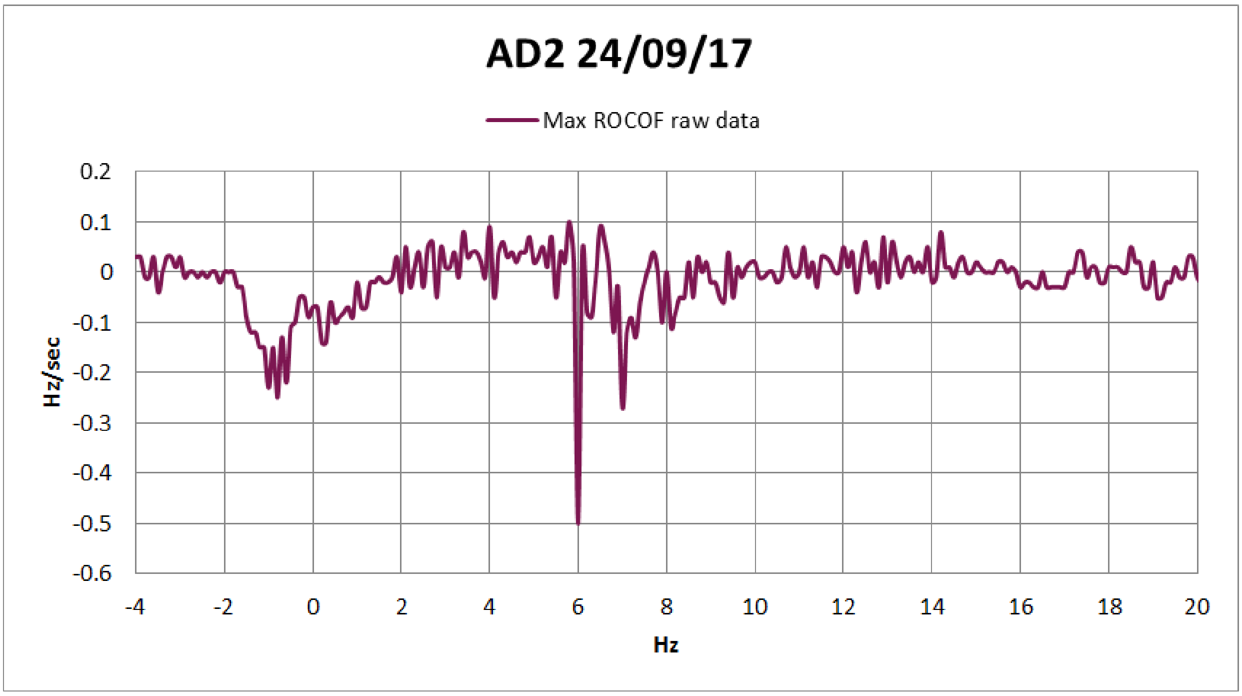
7.5 Whitegate – 08/09/17



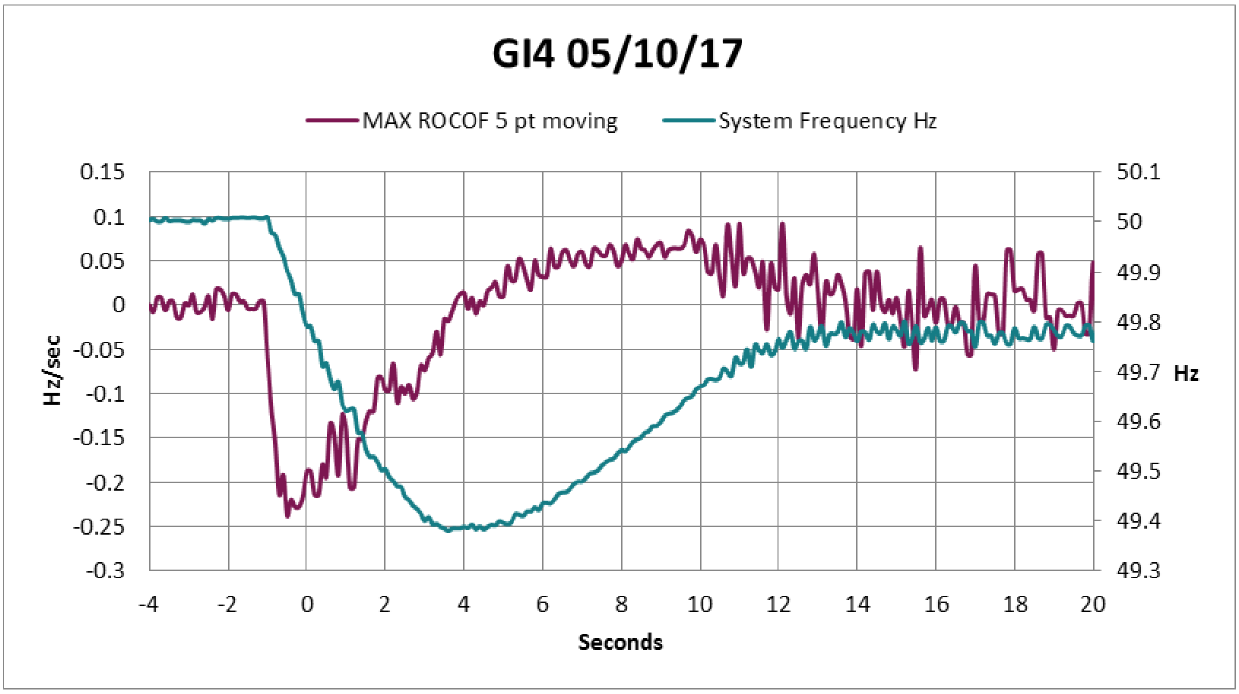


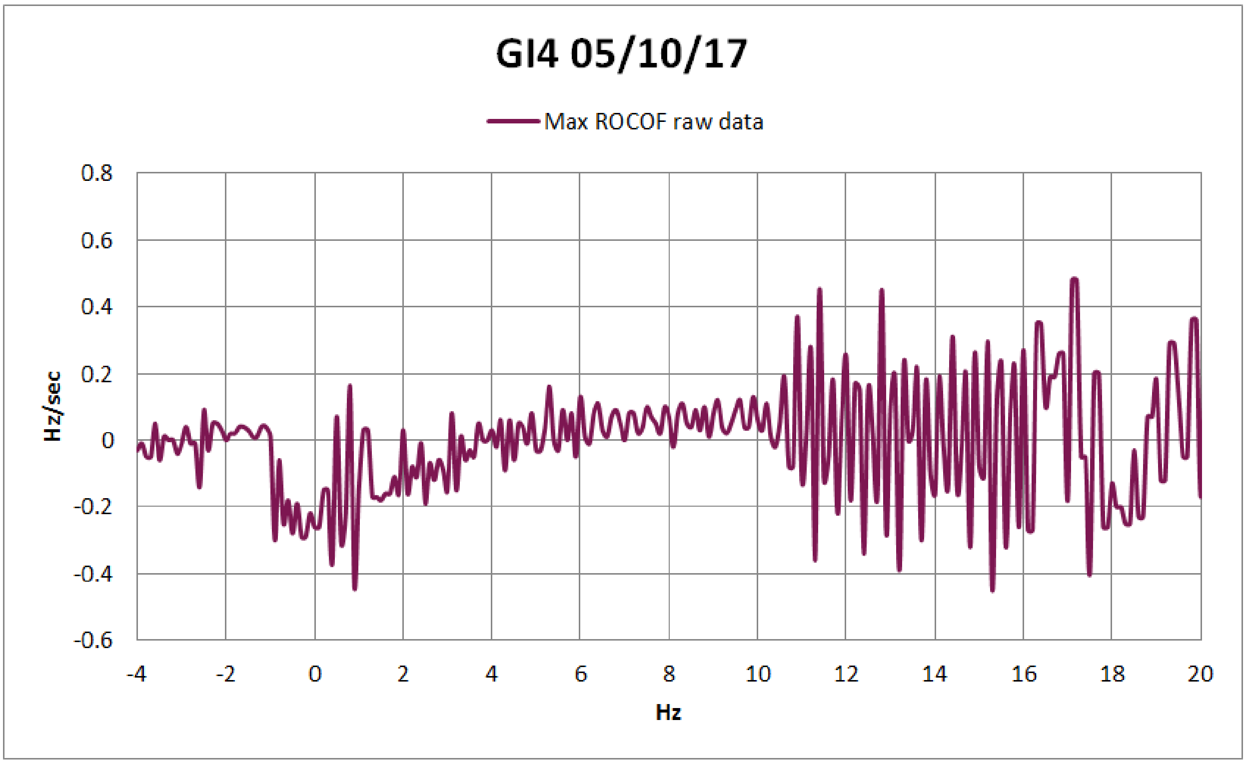
7.6 Aghada Unit 2 - 24/09/17



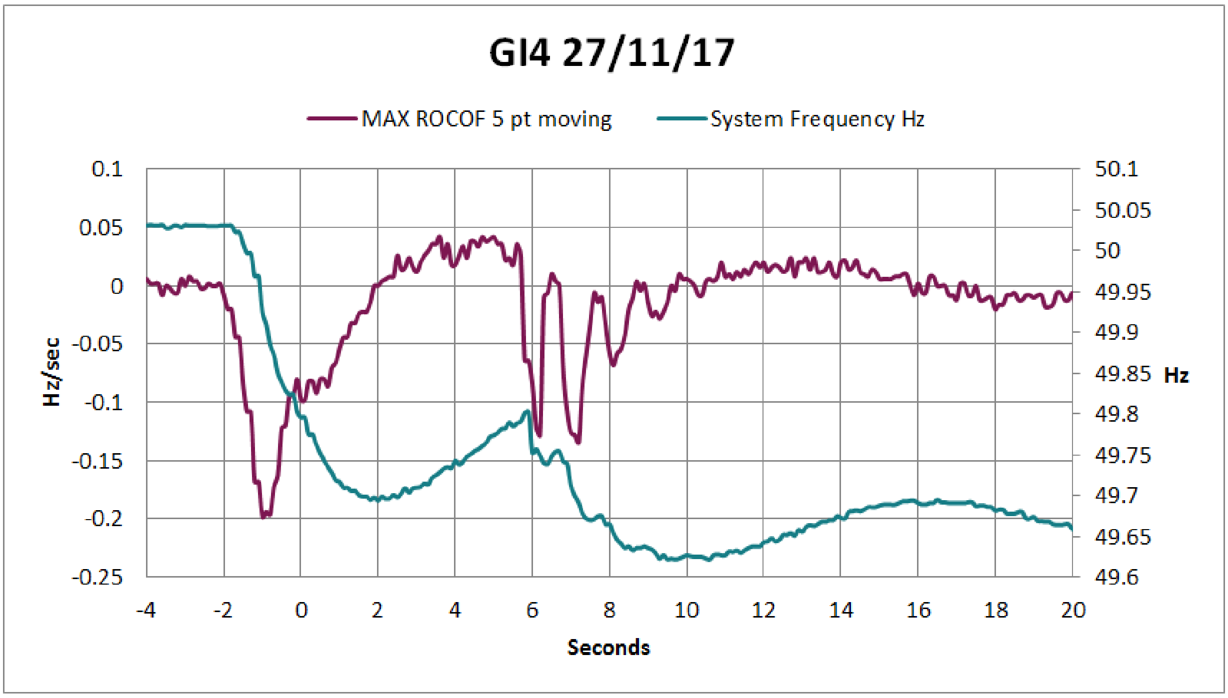


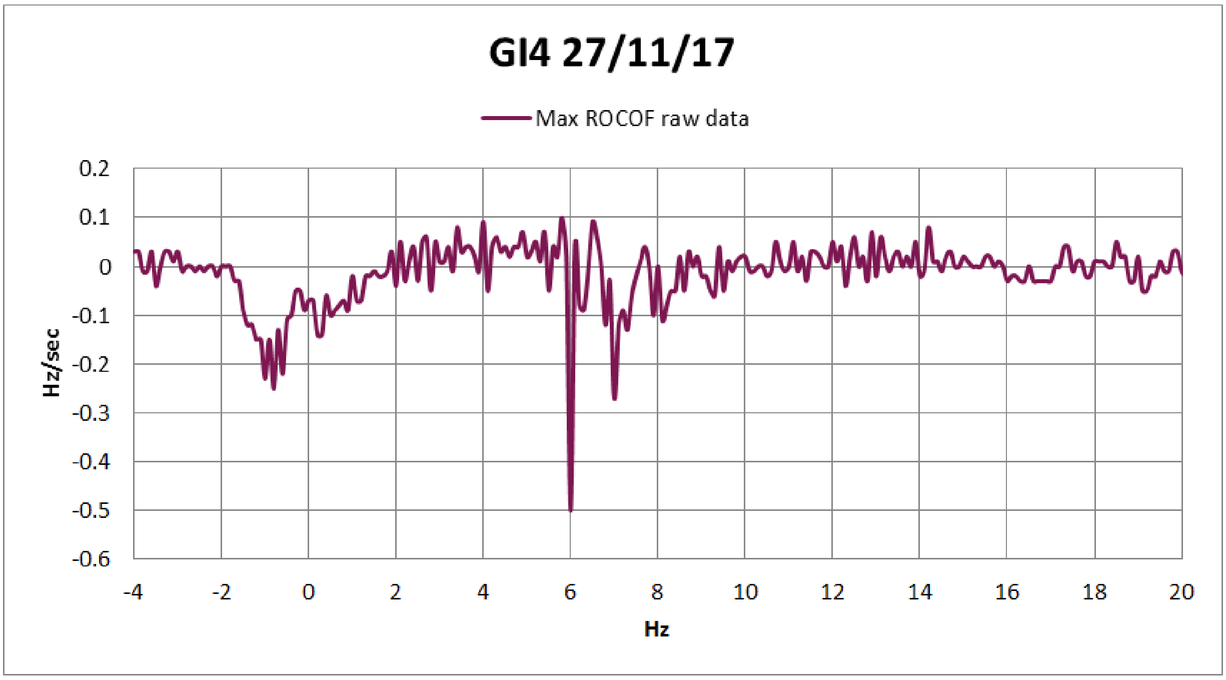
7.7 Great Island GI4 – 05/10/17





7.8 Great Island GI4 – 27/11/2017





8. Appendix 3 All Island Fully Dispatchable Generation Plant

Company	Unit	Capacity (MW)	Fuel	365-day Rolling Availability %
Activation Energy	AEDSU - AE1	89	DSU	35.04
	AEDSU - AE2	11	DSU	49.11
	AEDSU - AE3	14	DSU	67.24
	AEDSU - AE4	11	DSU	-
	AEDSU - AE5	15	DSU	52.75
Activation Energy Ltd (NI)	AE_DSU_NI - AEA	9	DSU	58.05
AC Automation	AC - ACA	6	DSU	86.39
AES	Ballylumford - B10	94	Gas / Distillate Oil	80.93
	Ballylumford - B21	249	Gas / Distillate Oil	88.26
	Ballylumford - B22	249	Gas / Distillate Oil	87.51
	Ballylumford - BGT1	58	Distillate	97.43
	Ballylumford - BGT2	58	Distillate	94.69
	Ballylumford - BPS4	144	Gas / Distillate Oil	99.37
	Ballylumford - BPS5	147	Gas / Distillate Oil	99.36
	Kilroot - KGT1	29	Distillate	98.62
	Kilroot - KGT2	29	Distillate	98.38
	Kilroot - KGT3	42	Distillate	56.01
	Kilroot - KGT4	42	Distillate	92.57
	Kilroot - KPS1	238	Coal / Heavy Fuel Oil	90.54
	Kilroot - KPS2	238	Coal / Heavy Fuel Oil	86.08
Aughinish Alumina Ltd	Seal Rock - SK3	85	Gas / Distillate Oil	84.03
	Seal Rock - SK4	85	Gas / Distillate Oil	91.94
Bord Gáis	Whitegate - WG1	444	Gas / Distillate Oil	93.94
Contour Global	Contour - CGA	12	Gas	99.32
Coolkeeragh ESB	Coolkeeragh - C30	408	Gas / Distillate Oil	92.78
	Coolkeeragh - CG8	53	Distillate	88.24
DAE Virtual Power Plant	DAE VPP - DP1	29	DSU	66.82
	DAE VPP - DP2	10	DSU	40.51
Dublin Waste To Energy	Dublin Waste - DW1	62	Waste to Energy	39.97
Edenderry Power Ltd	Edenderry - ED1	118	Peat	87.67
	Edenderry - ED3	58	Gas / Distillate Oil	99.12
	Edenderry - ED5	58	Gas / Distillate Oil	99.32
Electricity Exchange Limited	Elect Exchng - EE1	20	DSU	53.61
	Elect Exchng - EE2	18	DSU	72.54
	Elect Exchng - EE3	7.17	DSU	47.51
	Elect Exchng - EE4	8.61	DSU	42.27
	Elect Exchng - EE5	4.28	DSU	50.17
Electric Ireland DSU	Electric Irl - EI1	20	DSU	84.17

Company	Unit	Capacity (MW)	Fuel	365-day Rolling Availability %
Empower	EmpowerAGU - EMP	3	Distillate	91.88
Endeco Limited Ltd.	Endeco T Ltd - EC1	37	DSU	68.53
	Endeco T Ltd - EC2	9	DSU	65.65
	Endeco T Ltd - ECA	1	DSU	59.94
Endesa	Great Island - GI4	461	Gas / Distillate Oil	91.47
	Rhode - RP1	52	Distillate	98.57
	Rhode - RP2	52	Distillate	98.61
	Tarbert - TB1	54	Heavy Fuel Oil	98.71
	Tarbert - TB2	54	Heavy Fuel Oil	98.82
	Tarbert - TB3	241	Heavy Fuel Oil	98.57
	Tarbert - TB4	243	Heavy Fuel Oil	99.42
	Tawnaghmore - TP1	52	Distillate	98.97
	Tawnaghmore - TP3	52	Distillate	99.83
Energy Trading Ireland	Ener Trd Irl - ET1	11	DSU	76.57
	Ener Trd NI - ETR	18	DSU	55.28
Evermore Renewable Energy	Lisahally - LPS	17.6	Biomass	67.92
Indaver	Indaver - IW1	17	Waste to Energy	87.60
iPower	iPower AGU - AGU	74	Distillate	95.24
Powerhouse Generation Ltd. (NI)	PHG - PH1	20	DSU	72.17
	PHG - PH2	6	DSU	12.61
Powerhouse Generation Ltd.	Powerhouse G - PG1	7.011	DSU	78.36
Synergen	Dublin Bay - DB1	405	Gas / Distillate Oil	88.82
Tynagh Energy Ltd	Tynagh - TYC	384	Gas / Distillate Oil	95.36
Viridian Power and Energy	Huntstown - HN2	400	Gas / Distillate Oil	89.63
	Huntstown - HNC	342	Gas / Distillate Oil	93.78
	Viridian DSU - VE1	26	DSU	62.07
	Viridian DSU – VE2	6.30	DSU	39.61

Company	Unit	Capacity (MW)	Fuel	365-day Rolling Availability %
ESB Power Generation	Aghada - AD1	258	Gas / Distillate Oil	98.96
	Aghada - AD2	431	Gas / Distillate Oil	92.20
	Aghada - AT11	90	Gas / Distillate Oil	98.01
	Aghada - AT12	90	Gas / Distillate Oil	98.43
	Aghada - AT14	90	Gas / Distillate Oil	98.48
	Ardnacrusha - AA1	21	Hydro	65.21
	Ardnacrusha - AA2	22	Hydro	78.51
	Ardnacrusha - AA3	19	Hydro	71.37
	Ardnacrusha - AA4	24	Hydro	37.29
	Erne - ER1	10	Hydro	98.63
	Erne - ER2	10	Hydro	96.64
	Erne - ER3	22	Hydro	97.29
	Erne - ER4	22	Hydro	98.21
	Lee - LE1	15	Hydro	75.75
	Lee - LE2	4	Hydro	53.04
	Lee - LE3	8	Hydro	91.07
	Liffey - LI1	15	Hydro	98.13
	Liffey - LI2	15	Hydro	98.13
	Liffey - LI4	4	Hydro	56.88
	Liffey - LI5	4	Hydro	99.92
	Lough Ree - LR4	91	Peat	71.50
	Marina - MRC	95	Gas / Distillate Oil	95.66
	Moneypoint - MP1	285	Coal / Heavy Fuel Oil	93.19
	Moneypoint - MP2	285	Coal / Heavy Fuel Oil	91.38
	Moneypoint - MP3	285	Coal / Heavy Fuel Oil	88.64
	North Wall - NW5	104	Gas / Distillate Oil	95.40
	Poolbeg - PBA	232	Gas / Distillate Oil	53.94
	Poolbeg - PBB	232	Gas / Distillate Oil	85.42
	Turlough H - TH1	73	Hydro - Pumped Storage	70.62
	Turlough H - TH2	73	Hydro - Pumped Storage	70.95
	Turlough H - TH3	73	Hydro - Pumped Storage	70.94
	Turlough H - TH4	73	Hydro - Pumped Storage	70.27
	West Offaly - WO4	137	Peat	85.90

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

10. Appendix 5 Formulae (EirGrid Transmission System)

10.1 Availability & Unavailability Formula

Equation 2: 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

Equation 3: 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 (at that voltage level) for which outages occurred

m = The total number of transformers at that voltage level

Equation 4: System Unavailability

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

Equation 4 is the same as that used by OFGEM (The Office of Gas and Electricity Markets) in the UK.

10.2 System Minute Formula

Equation 5: System Minute Formula

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

Equation 6: System Minute Formula

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

Where: Power factor = 0.9