All-Island Transmission System Performance Report
2015

SONI EIRGRID

Table of Contents

Table of Figures

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 2015. This report contains transmission system data and performance statistics for the transmission system in Ireland and Northern Ireland for the year 2015 (1st January 2015 – 31st December 2015). 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 Energy Regulation (CER).

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 of Enterprise Trade and Investment.

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 2015 against the criteria approved by the CER,
- Section 5 details the performance of the SONI TSO business during 2015 against the criteria approved by the Utility Regulator in Northern Ireland (URegNI).

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 2015 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 IE and NI
- 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 6392 MW on Monday the 19th January 2015. The minimum all-island demand was 2295 MW was occurred on Sunday 19th July 2015.
- The all-island installed capacity of conventional, dispatchable generation in December 2015 was 9357 MW.
- In 2015 a maximum all-island wind generation level of 2607 MW occurred on Saturday the 19th of December 2015.
- In 2015 the system frequency was operated within 49.9 Hz and 50.1 Hz for 99.4% of the time
- In 2015 the system was operated at all times within acceptable international standards for safety, security and reliability of customer supplies.

Ireland

- In 2015 the availability of the East West Interconnector was 97.55%.
- The average plant availability in Ireland in 2015 was 94.42%.
- The System Minutes lost for 2015, attributable to EirGrid, was 0.049.

Northern Ireland

- The availability of the Moyle Interconnector for 2015 was 49.62%.
- The average availability of the Northern Ireland transmission system was in 2015 was 96.83%.
- The System Minutes lost for 2015, in Northern Ireland was 2.606, 2.519 of which can be attributed to an incident at Castlereagh 110 kV substation in April.

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 Northern Ireland is operated at 275 kV and 110 kV. The transmission system in Ireland is operated at 400 kV, 220 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 Northern Ireland and 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

The 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 2014 & 2015

	2014	2015
All-Island Total Exported Energy [GWh]	34,960	35,735
Ireland Total Exported Energy [GWh]	26,195	26,959
Northern Ireland Total Exported Energy [GWh]	8,765	8,776

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 2015 was 6392 MW and occurred at 17:30 on Monday 19th of January.

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 2015 a minimum all-island demand of 2295 MW was recorded at 05:45 on Sunday 19th July.

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 2607 MW was achieved on Saturday the 19th of December. Table 1 provides a summary of the system records for 2014 and 2015.

Table 2: System Records 2014 & 2015

	2014	2015
Winter Peak Demand [MW]	6310	6392
Minimum Summer Night Valley [MW]	2191	2295
Maximum Wind Generation [MW]	2314	2607

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 2015 was 9357 MW (7,166 MW in Ireland and 2215 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 December 2015 was 3,041 MW (2,400 MW in Ireland and 641 MW in Northern Ireland).

Appendix 1 provides a list of the fully dispatchable generating units connected to the transmission system.

3.5 Generation Availability

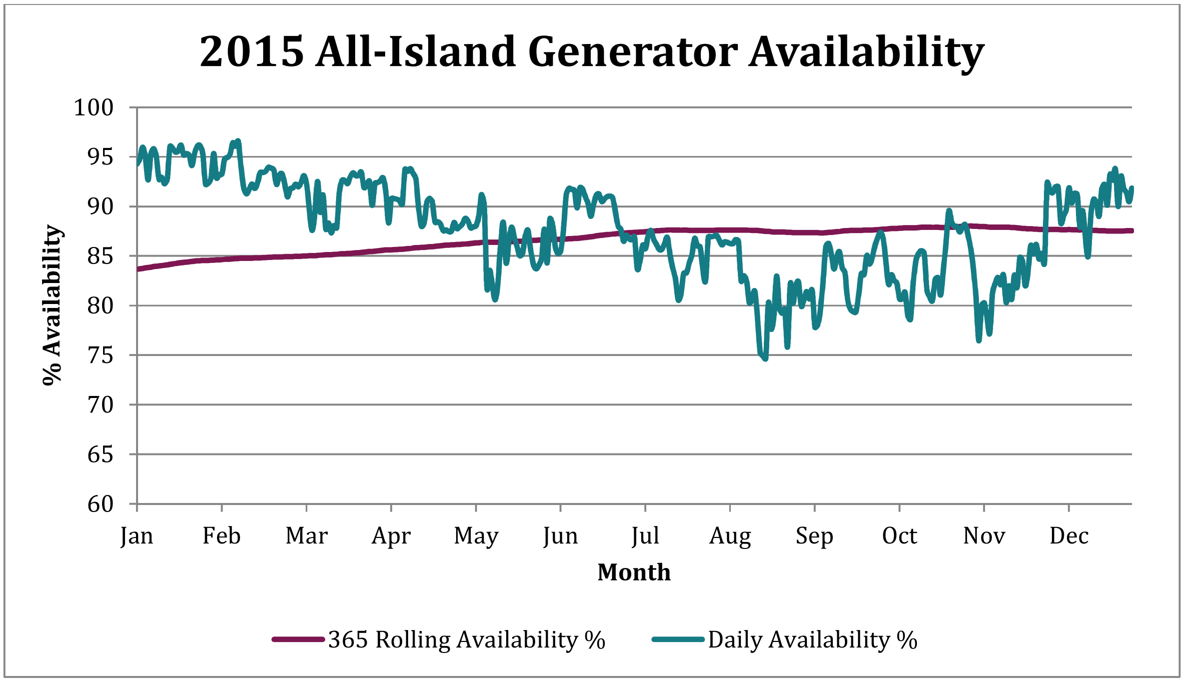
Generation Availability is a measure of the capability of a generator to deliver power in a given period to the transmission system. In order for EirGrid and SONI to operate a secure and reliable transmission system in an economic and efficient manner, it is necessary for generators to maintain a high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

Generation system availability is calculated on a daily and 365-day rolling average basis[2]. Figure 1 shows the daily and 365-day rolling average availability for 2014.

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

2 365-day rolling average is a capacity weighted average availability over the previous 365 days

Figure 1: Generation System Availability 2015

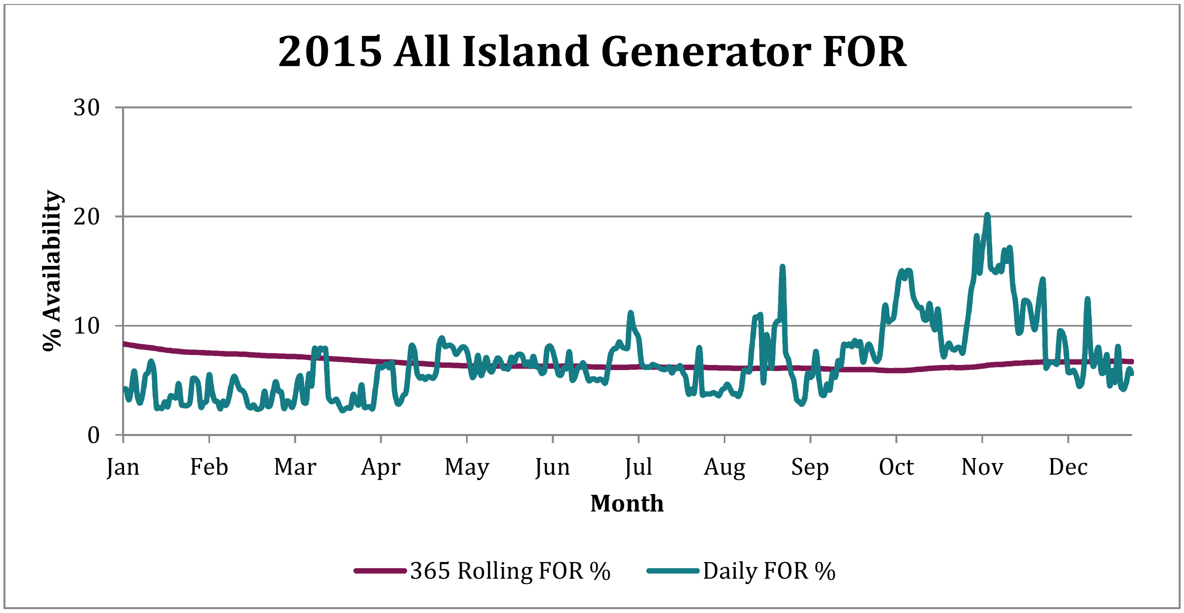


- The average daily generation system availability in 2015 was 87.58%
- The maximum daily generation system availability in 2015 was 96.56%, occurring on the 7th of February.
- The minimum daily generation system availability in 2015 was 74.63%, occurring on the 19th of August.

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 2015



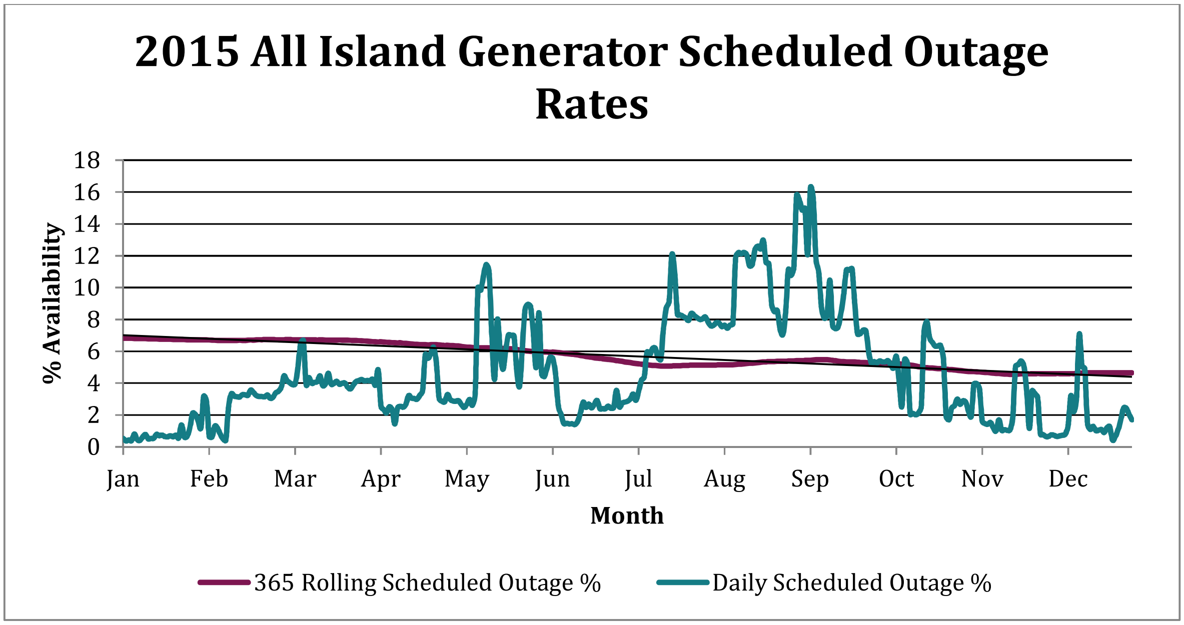
- The average daily generation system forced outage rate in 2015 was 10.07%.
- The highest forced outage rate in 2015 was 20.06%, occurring on the 9th of November. On this date the following units were on a forced outage: Great Island GI4, Moneypoint MP3, Ballylumford B31 and Coolkeeragh GT8.
- The minimum daily generation system forced outage rate in 2015 was 2.23%.

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 2015



- The average daily generation system scheduled outage rate in 2015 was 4.64%.
- The maximum daily generation system scheduled outage rate in 2015 was 16.27%, occurring on the 6th of September.
- The minimum daily generation system scheduled outage rate in 2015 was 0.37%.

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 acceptable international standards for safety, security and reliability of customer supplies. 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 0.049 in 2015. No System Minutes were lost due to the disconnection of Normal Tariff load customers during 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 2015 the system frequency was within the agreed limits for 99.4% of the time.

Extensive maintenance of the transmission system was carried out throughout the year, including 7,791 km of overhead line patrols.

4.2 Transmission Infrastructure

The transmission system is a meshed network of high voltage lines and cables (110 kV, 220 kV, 275 kV and 400 kV) for the transmission of bulk electricity supplies around Ireland. This excludes the Dublin 110 kV network and some other specific 110 kV circuits which are treated as part of the distribution system. Table 3 provides a summary of transmission system infrastructure for 2015 and 2014.

Table 3: Transmission System Infrastructure 2014 & 2015

	2014		2015	
Plant Type	No. of Items	Circuit Length [km]	No. of Items	Circuit Length [km]
110 kV Circuits	199	4268	203	4342
220 kV Circuits	55	1917	56	1927
275 kV Circuits	2	97	2	97
400 kV Circuits	4	439	4	439
Circuit Total	260	6721	265	6799
Plant Type	No. of Items	Transformer Capacity [MVA]	No. of Items	Transformer Capacity [MVA]
220 / 110 kV Transformers	46	8739	46	8739
275 / 220 kV Transformers	3	1200	3	1200
400 / 220 kV Transformers	7	3550	7	3550
Transformer Total	56	13489	56	13489
Total No. of Substations	153		154	

4.3 Grid Development and Maintenance

This section provides an overview of grid development activities in 2015.

4.3.1 Completed Capital Projects

Over the course of 2015 the following capital projects were completed:

- Ikerrin - Thurles 110kV line uprate incl. Thurles BB uprate
- Carrick-on-Shannon 110kV Station BB uprate
- Woodhouse 110kV connection shallow works
- Carrigadrohid - Macroom 110kV line uprate- Line Works
- Cunghill - Sligo 110kV line uprate
- Cahir - Tipperary 110kV Line Uprate (Including Tipperary Busbar)
- Maynooth - Ryebrook 110kV line uprate - Line Works Internal (EM1 - AM26)
- Cloghboola Wind Farm (Shallow Works) - linked to CP0500
- Dunfirth - Kinnegad - Rinawade 110kV refurbishment
- Dunstown - Turlough Hill 220kV line refurbishment
- Boggeragh 2WF Extension (new bay in Boggeragh)
- Kilbarry 110kV Station Replacement of three 110kV CBs

- Finglas 220kV station (T2101) transformer replacement project
- Cullenagh Knockraha Polymeric Insulator Replacement

4.3.2 New Connection Offers Issued

Parties seeking a new connection to the transmission system or to amend an existing Connection Agreement must apply to EirGrid for a connection offer. EirGrid operates a standard regulatory approved process for providing Connection Offers to generators and demand customers seeking direct connection to the transmission system. Table 4 details the number of new connection offers made by EirGrid in 2015.

Table 4: New Demand & Generation Connection Offers Issued 2015

	Demand	Generation
New Connection Offers Issued in 2015 [No.][3]	1	0
New Connection Offers Issued in 2015 [MW Capacity]	53.33 MVA	0 MW

4.3.3 New Connection Offers Accepted

In order to connect to the transmission system, all demand and generation customers must execute a Connection Agreement with EirGrid. Table 5 summarises the total number of executed Connection Agreements in 2015 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 5: Executed Demand & Generation Connection Agreements in 2015

	Demand	Generation
Executed Connection Offer Agreements in 2015 [No.]	0	1
Executed Connection Offer Agreements in 2015 [Capacity]	0 MVA	330 MW

As well as the connection offers issued and accepted there has been a significant increase in the work done to modify connection agreements held by existing customers in 2015.

[3] These figure do not include non-capacity connection offers, decreases in MEC and termination of offers

4.3.4 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 6 provides an overview of the number of new connections to the transmission system commissioned in 2015.

Table 6: Demand & Generation Connections Energised in 2015

	Demand	Generation
Connections Energised in 2015 [No.]	0	4
Connections Energised in 2015 [Capacity]	0 MVA	132 MW

4.3.5 Customers Certified Operational

Table 7 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.

Table 7: Customers Certified Operational in 2015

	Total No. of sites Certified Operational 2015
Customers Certified Operational [Total No. of sites]	13
Customers Certified Operational [MW Capacity]	198

As of the end of 2015, there were a total of 12 Demand Side Units (DSU) certified as operational with a total capacity of 251 MW.

4.3.6 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 on critical items 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. 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, CAPEX 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 8 provides, in volume terms, a summary of transmission maintenance requirements, maintenance programmed and maintenance completed in 2015 for overhead lines, underground cables and transmission stations. In order to facilitate more maintenance work and CAPEX 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 8: Maintenance Summary for 2015

Volume of Transmission Maintenance by Activity	Maintenance Requirements	Maintenance Programme Year End	Maintenance Completed
Overhead Line Maintenance			
Patrols (incl. Helicopter, climbing, infrared & Bolt)	9,221	9,221	7,791
Timber Cutting [km]	44	44	23
Structure & Hardware Replacement [Number]	74	80	57
Insulator & Hardware Replacement [Number]	234	233	29
Underground Cable Maintenance			
Alarm Checks / Inspection [Number]	620	750	597
Station Maintenance			
Ordinary Service [Number]	509	332	240
Operational Tests [Number]	1037	1028	807
Condition Assessment of Switchgear [Number]	275	147	106
Tap Changer Inspection [Number]	13	12	8
Corrective Maintenance Tasks [No. of Tasks]	530	596	349

4.4 General System Performance

4.4.1 Under Frequency Load Shedding

There were no Under Frequency Load Shedding (UFLS) disturbances in 2015 which resulted in shedding of Normal Tariff (NT) load customers. Short Term Active Response (STAR) interruptible load customers were disconnected on three occasions. Two UFLS disturbances were due to large generator trips. One UFLS disturbance was due to a tripping of the East West Interconnector.

Table 9 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 2015 was 49.09 Hz; during the second UFLS disturbance.

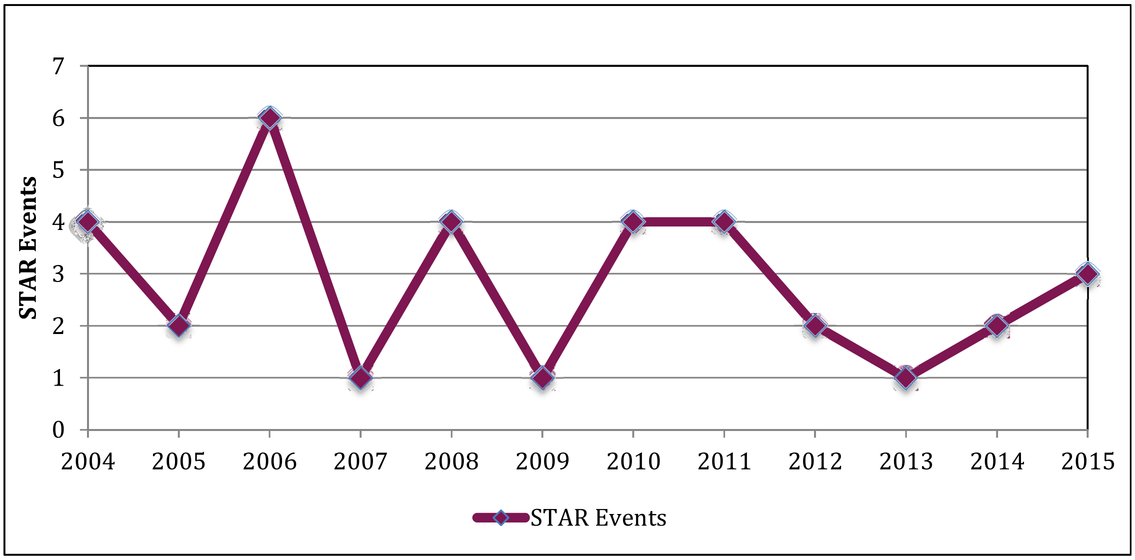
Table 9: Summary of UFLS disturbances in 2015

SDR No.	Date	Unit	MW	Freq, Hz	49.9 Hz, min	MVA Minutes	STAR SM	NT SM
T022/2015	14/03/15	Gen	470	49.31	0.11	24.28	0.004140	0
T035/2015	22/06/15	EWIC	524	49.09	7.07	341.57	0.058233	0
T038/2015	07/07/15	Gen	344	49.28	1.45	101.45	0.017297	0

The target for activation of STAR schemes is 16 events or lower for the year. The number of STAR events each year since 2004 is presented in Figure 4. The average over this period was 2.8 ± 1.6

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.

Figure 4: Number of STAR events 2004 - 2015



4.4.2 Under Voltage Load Shedding

There was no incident of Under Voltage Load Shedding in 2015.

4.4.3 System Minutes Lost

The total System Minutes lost for 2015, attributable to EirGrid, was 0.049.

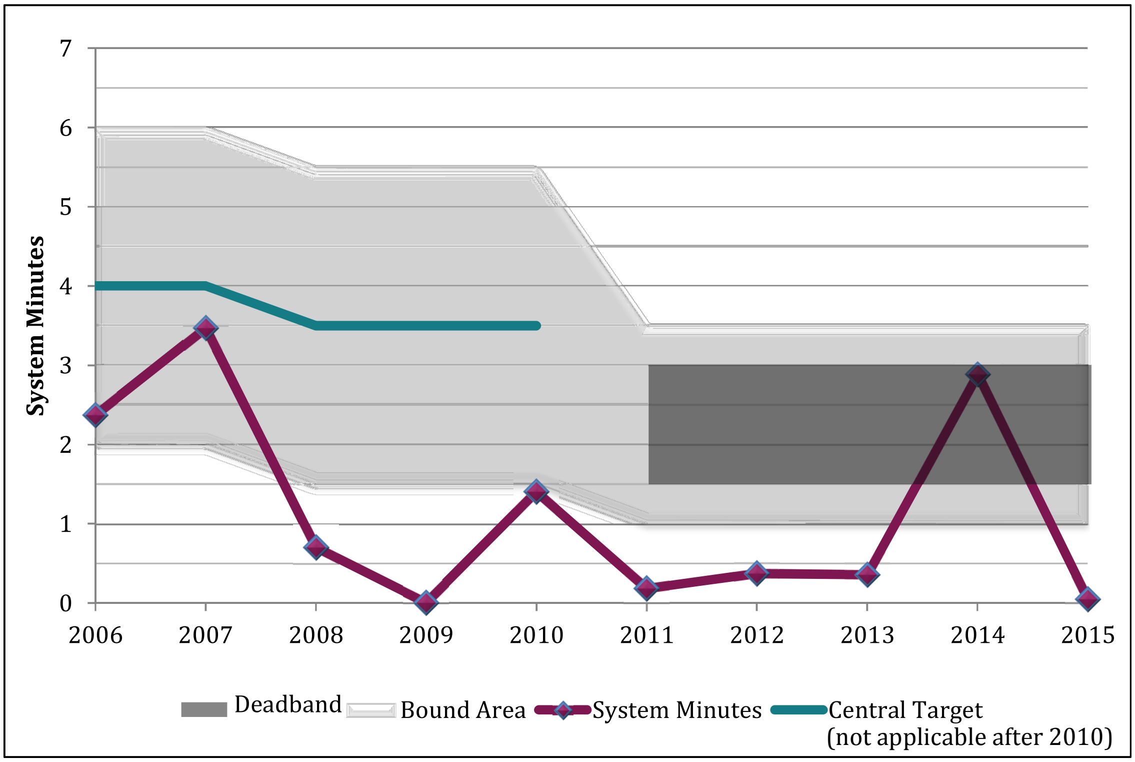
The System Minutes lost as a result of faults on the Main System was 0.049 in 2015. No System Minutes were lost due to the disconnection of Normal Tariff load customers during UFLS disturbances.

The trend of System Minutes lost since 2006 is shown in Figure 5, with incentive target areas and deadband, as provided by the CER. The average number of System Minutes lost since 2006, attributable to EirGrid, was 1.22 ± 1.29.

The central target provided up to 2010[4] was replaced with a deadband in 2011[5]. The deadband is between 1.5 SM and 3.0 SM, where there is neither penalty nor incentive. EirGrid is rewarded one fifth of the incentive amount for every 0.1 SM below 1.5 SM, down to 1.0 SM. EirGrid is penalised one fifth of the incentive amount for every 0.1 SM above 3.0 SM, up to a maximum penalty at 3.5 SM.

4 CER09004: TSO System Performance Incentives (SPIs) for 2009 & 2010
5 CER11128: Decision on 2011/2012 Transmission Incentives

Figure 5: System Minutes attributable to EirGrid 2006 - 2015

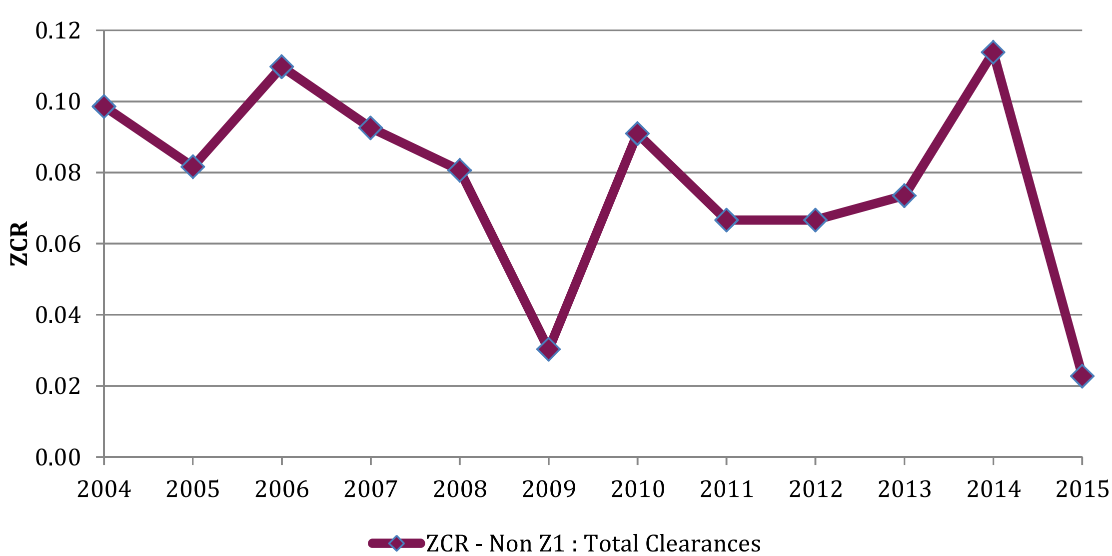


4.4.4 Zone Clearance Ratio

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 2015, the ZCR was 0.023. The ZCR trend since 2004 is shown in Figure 6.

Figure 6: Zone Clearance Ratio 2004 - 2015



The number of Zone 1, non-Zone 1 and Zone 2 clearances for each year are presented in Table 10. There were 45 short circuit faults cleared by protection on the Main System. This figure is made up of 38 Main System short circuits faults and six Non Main System faults.

Of the 44 short circuit faults cleared by Main System protection, 43 were cleared in Zone 1 and one was cleared in Zone 2.

Table 10: Number of Zone 1, non-Zone 1 and Zone 2 clearances 2004 - 2015

Clearance	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Zone 1	64	45	73	49	57	32	20	28	28	63	109	43
Non Zone 1	7	4	9	5	5	1	2	2	2	5	14	1
Zone 2	7	2	6	5	2	1	2	2	2	4	14	1

The Zone 2 clearance occurred on the Cullenagh - Dungarvan 110 kV line on Tuesday 17 November 2015. The slow clearance was due to failure of permissive teleprotection signals to reach the protection relays at the Dungarvan end to allow accelerated tripping.

4.4.5 Frequency Control

In 2015 the system frequency was operated between 49.9 Hz to 50.1 Hz for 99.4% of the time. This figure of 99.4% exceeds the 2015 target of 94%.

4.5 Summary of Important Disturbances

4.5.1 Loss of Load

T57/2015: Carrick on Shannon

At 03:17 hours on Sunday 11 October 2015, the Flagford - Lanesboro 110 kV line tripped, reclosed and tripped for a fault involving S phase. High resistance developed on S phase as a mid-span joint began to fail. This developed into an open circuit and subsequently into a single phase to ground fault (SE) when the conductor came down across an MV line. When the 110 kV conductor came down across an MV line, this caused the shorting of a pole mounted transformer and the operation of a fuse which disconnected customers on a 20 kV spur supplied from Carrick on Shannon. Approximately 0.08 MW of load was disconnected for up to 14 hours 15 minutes. 0.009011 System Minutes were lost to Normal Tariff customers.

T60/2015: Arigna

At 08:14 hours on Friday 16 October 2015, T121 110 kV CB in Arigna was tripped by its under frequency protection. The cause of the fault was an incorrect protection setting. 3.5 MW of load fed from Arigna, which is Tee connected between Carrick on Shannon and Corderry, was disconnected for up to 1 hour 52 minutes. 0.027799 System Minutes were lost to Normal Tariff customers.

T68/2015: Tullabrack

At 06:10 hours on Friday 13 November 2015, the Moneypoint/Tullabrack 110 kV CB in Booltiagh tripped for a three phase fault on the Booltiagh - Moneypoint - Tullabrack 110 kV line. The cause of the fault was lightning. 6.6 MW of load fed from Tullabrack, which is Tee connected between Booltiagh and Moneypoint, was disconnected for up to 15 minutes. 0.012621 System Minutes were lost to Normal Tariff customers.

4.5.2 Under Frequency Load Shedding

T22/2015: CCGT Trip

At 16:51 hours on Saturday 14 March 2015, a CCGT tripped from 470 MW. System frequency dropped from 50.01 Hz to 49.31 Hz at nadir. The frequency recovered to 49.9 Hz within seven seconds. The STAR scheme was activated during this incident, which resulted in the disconnection of 12.3 MW of interruptible Industrial Customer load for 1 minute 46 seconds. 0.004140 STAR System Minutes were lost. The System Minutes lost during this incident relate entirely to contracted STAR customers.

T35/2015: Interconnector Trip

At 09:56 hours on Monday 22 June 2015, the East West Interconnector tripped from 524 MW import. A CCGT subsequently tripped from 115 MW. System frequency dropped from 50.02 Hz to 49.09 Hz at its nadir. The frequency recovered to 49.9 Hz in approximately seven minutes. The STAR scheme was activated during this incident, which resulted in the disconnection of 35.2 MW of interruptible Industrial Customer load for 8 minutes 44 seconds. 0.058233 STAR System Minutes were lost. The System Minutes lost during this incident relate entirely to contracted STAR customers.

T38/2015: CCGT Trip

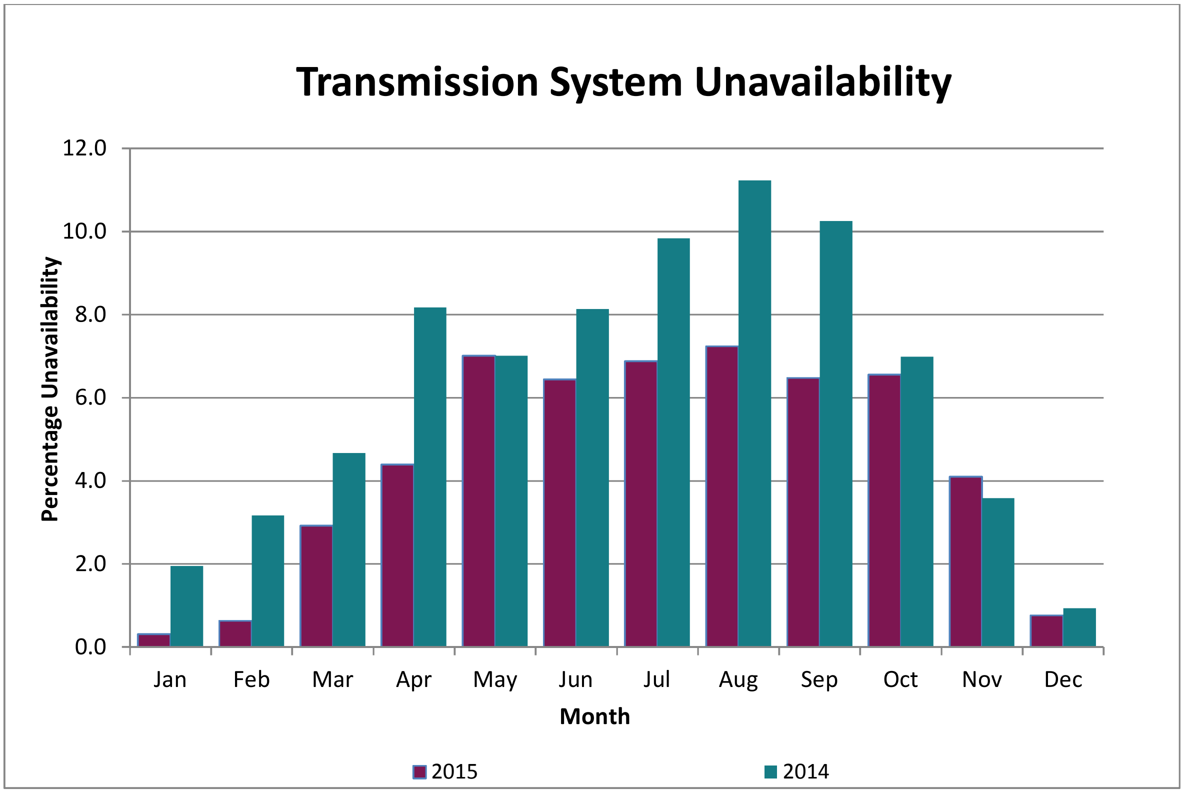
At 14:52 hours on Tuesday 07 July 2015, a CCGT tripped from 344 MW. System frequency dropped from 49.98 Hz to 49.28 Hz at nadir. The frequency recovered to 49.9 Hz within two minutes. The STAR scheme was activated during this incident, which resulted in the disconnection of 29.3 MW of interruptible Industrial Customer load for 3 minutes 7 seconds. 0.017297 STAR System Minutes were lost. The System Minutes lost during this incident relate entirely to contracted STAR customers.

4.6 Transmission System Availability & Outages

4.6.1 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 2014 and 2015.

Figure 7: Monthly Variations of System Unavailability 2014 & 2015



4.6.2 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 11 provides a detailed breakdown of all plant availability figures for 2014 and 2015.

Table 11: Transmission System Plant Availability 2014 & 2015

Plant Type	Circuit Length [km]	Number of Outages	Availability (%) 2014	Availability (%) 2015
110 kV Circuits	4342	378	92.63	95.17
220 kV Circuits	1927.1	88	95.8	95.01
275 kV Circuits	97	3	95.89	98.18
400 kV Circuits	439	7	97.17	93.58
Plant Type	**Transformer Capacity [MVA]**	**Number of Outages**	**Availability (%) 2014**	**Availability (%) 2015**
220 / 110 kV Transformers	8739	130	95.26	92.02
275 / 220 kV Transformers	1200	7	98.7	97.52
400 / 220 kV Transformers	3550	26	92.98	93.73
Total	6737.3 km 13489 MVA	639	95.49	95.03

In 2015:

- The average plant availability was 94.42%;
- The maximum availability by plant type was 98.18%, which occurred on the 275kV tie lines; and
- The minimum availability by plant type was 92.02%, which occurred on the 220/110kV transformers.

4.6.3 Cause of Transmission Plant Unavailability

Transmission plant unavailability is classified into the categories outlined in Table 12.

Table 12: 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.

Category	Description
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.

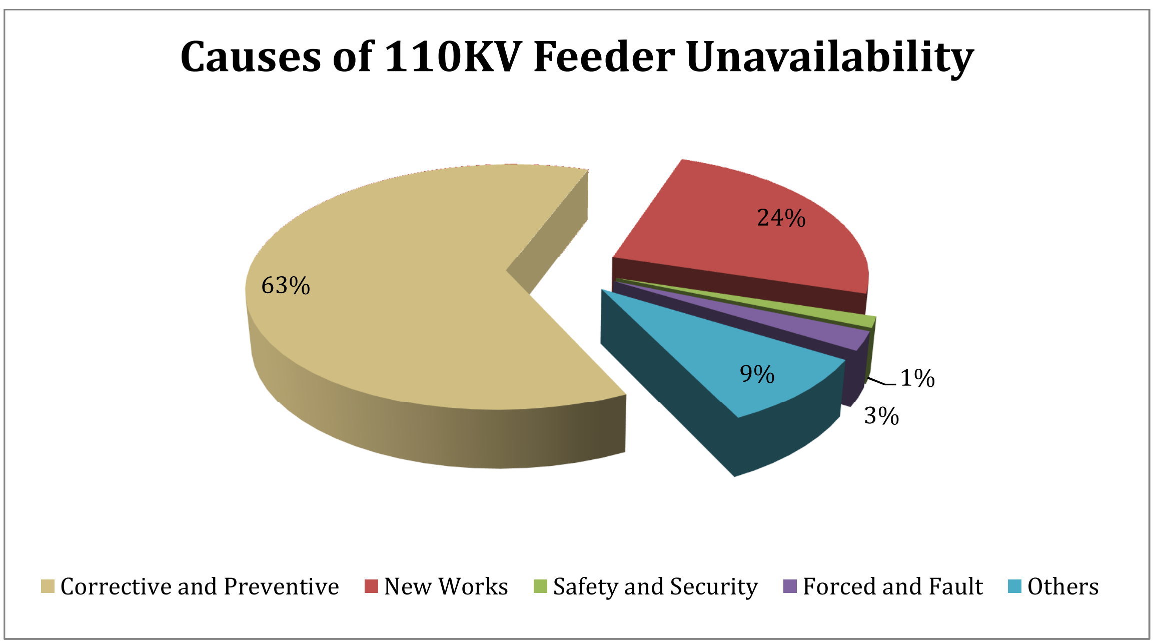
4.6.4 110 kV Plant Unavailability

Figure 8 provides a breakdown of the causes of unavailability on the 110 kV network in 2015.

The largest contributor to unavailability (63%) on the 110 kV network in 2015 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 Tarbert-Tralee 2 110kV Circuit, which lasted 225 days. This was to facilitate maintenance on the associated cubicles and also to facilitiate the looping in of Kilpaddoge station.

A further 24% 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 Arigna tee Carrick on Shannon 110 kV line. The purpose of this outage was protection upgrades and insulator changes and it lasted for 191 days.

Figure 8: Causes of Unavailability on the 110kV System in 2015



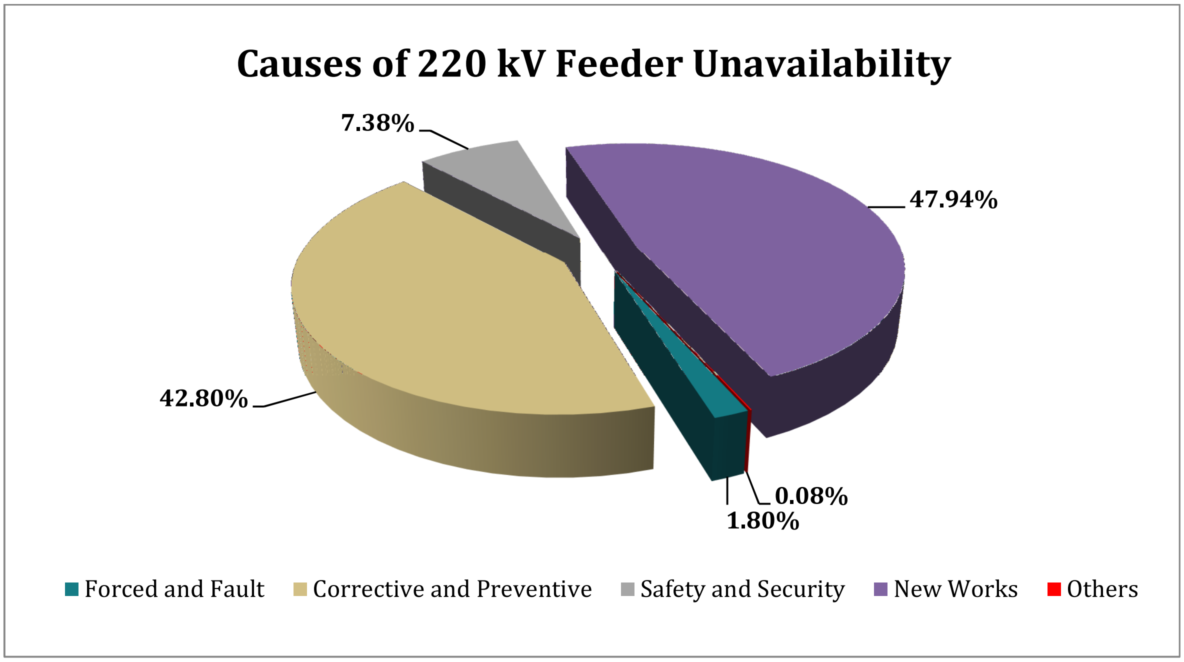
4.6.5 220 kV Plant Unavailability

Figure 9 provides a breakdown of the causes of unavailability on the 220 kV network in 2015.

The largest contributor to unavailability (47.94%) on the 220 kV network in 2015 were also outages for the purpose of New Works. The most significant of these was the outage of the Clashvoon-Tarbert 220kV Line to accommodate the looping in of Ballyvouskill station which lasted for 148 days.

Approximately 43% of unavailability on the 220 kV network was attributable to Corrective and Preventative Maintenance. The most significant of these outages was on the Cullenagh-Knockraha 220 kV line which lasted 55 days. The purpose of this was to install new insulators.

Figure 9: Causes of Unavailability on the 220kV System in 2015



4.6.6 275 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 2015 there were only 3 outages of 275 kV tie-lines, all of which were for corrective and preventative maintenance. The longest of these was a 10 day outage of Louth - Tandragee 2 (TWO) 275 kV Line to facilitate maintenance.

4.6.7 400 kV Plant Unavailability

Figure 10 provides a breakdown of the causes of unavailability on the 400 kV network in 2015.

The largest contributor to unavailability (94.68%) on the 400 kV network in 2015 were corrective and preventative outages. The most significant of these was a maintenance outage of the Oldstreet - Woodland 400kV line which as a result remained on forced outage for 20 days.

Figure 10: Causes of Unavailability on the 400kV System in 2015

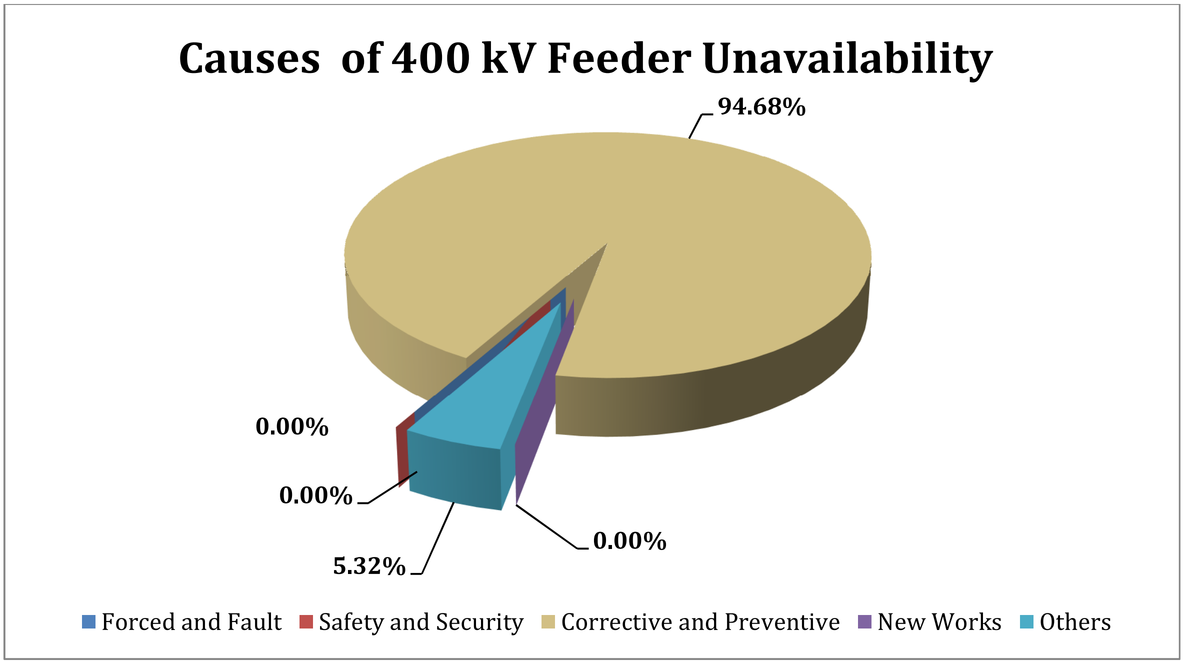


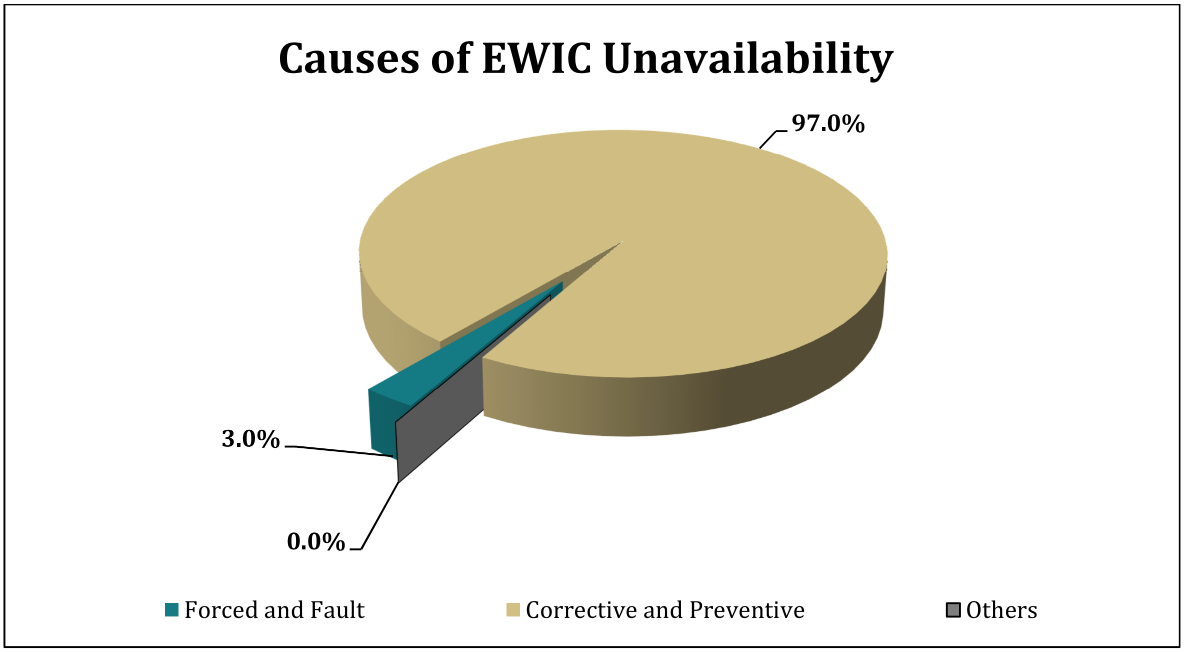
Table 13 provides a breakdown of the transmission system outages that occurred in 2015 by plant type.

Table 13: Transmission System Plant Outage 2015

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	**203**	4342	23	25	41	259	30	378
220 kV Circuits	**56**	1927.1	8	8	8	56	8	88
275 kV Circuits	**2**	97	0	0	0	3	0	3
400 kV Circuits	**4**	439	0	0	0	5	2	7
Total	265	6799	31	33	49	323	40	476
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	46	8739	10	6	15	76	24	131
275 / 220 kV Trafos	3	1200	0	0	0	7	0	7
400 / 220 kV Trafos	7	3550	8	0	0	16	2	26
Total	56	13489	18	6	15	99	26	164

4.6.8 East West Interconnector Unavailability

Figure 11: Causes of East West Interconnector Unavailability in 2015

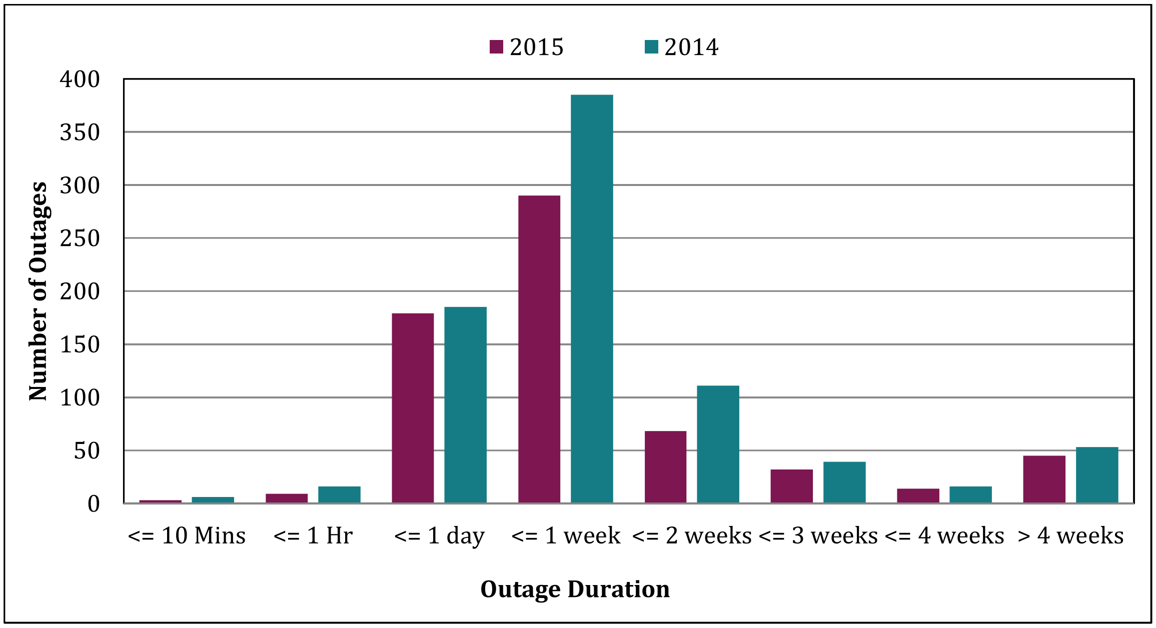


In 2015 the availability of the East West Interconnector was 97.55%. Of the outages contributing to EWIC unavailability, Corrective & Preventative maintenance represented the largest portion (97%), the longest of which was a four day outage to perform annual maintenance.

4.6.9 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 2014 & 2015



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.

4.6.10 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 which 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 124 day outage to refurbish the Raffeen-Trabeg 1 (One) 110KV Line and the 150 day outage of the Maynooth-Ryebrook 110KV line.

Figure 13: Percentage unavailability in each month of 2014 & 2015

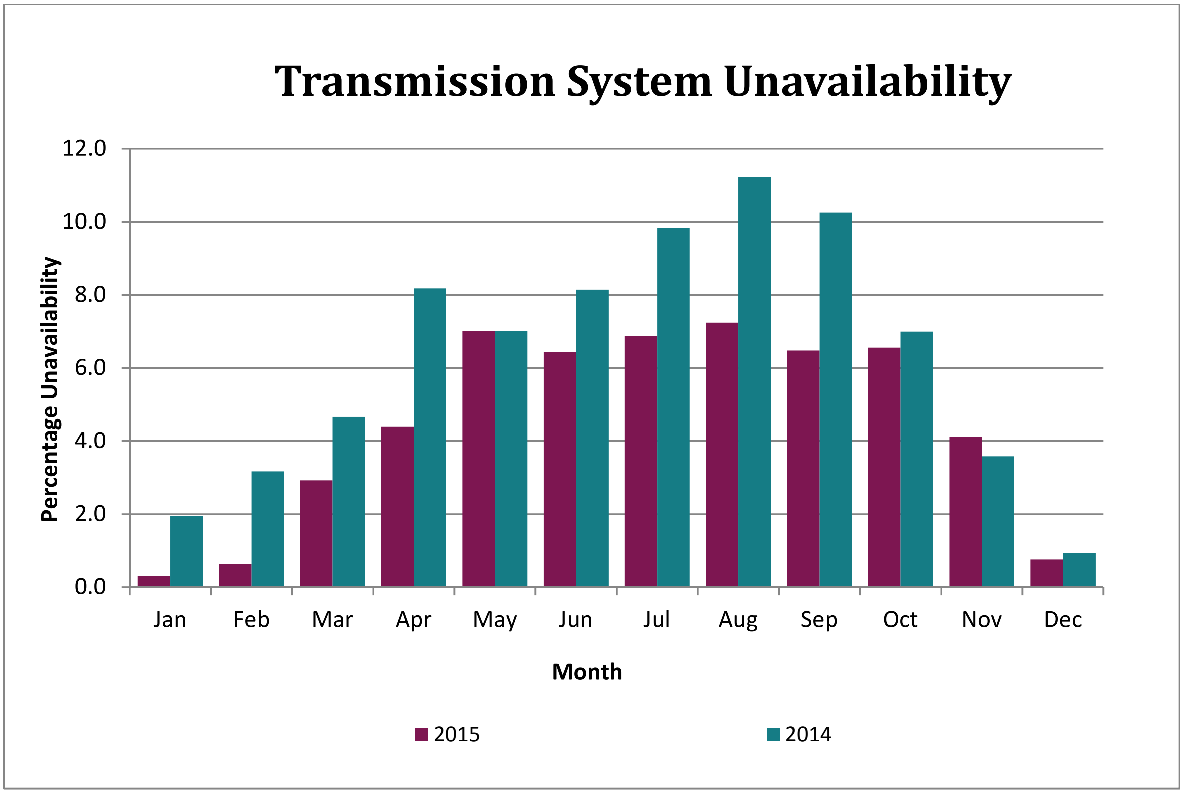
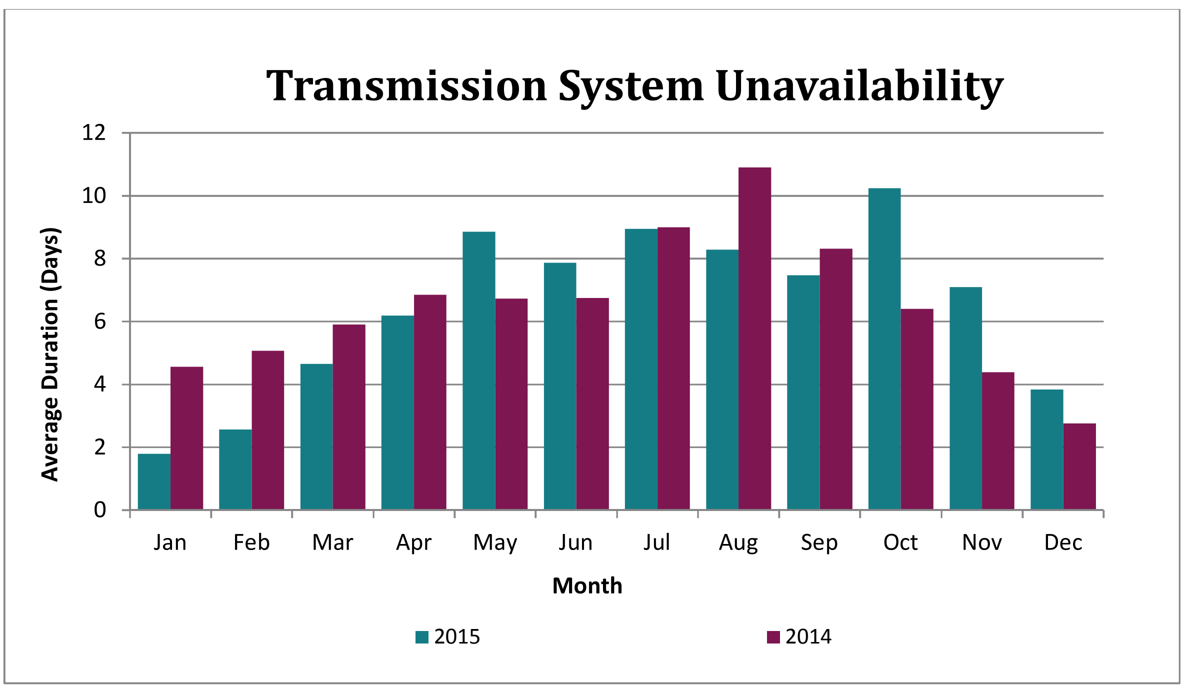


Figure 14: Average duration of outages 2014 & 2015



4.6.11 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. There are three types of forced outages:

Fault & Reclose
This type of outage occurs when a fault is detected by the protection equipment; the transmission plant is disconnected and successfully reconnected immediately, thus re-energising the circuit. These represent temporary faults, which, in general, do not cause major disruption to the system or customer. Lightning is a typical cause of this type of outage.

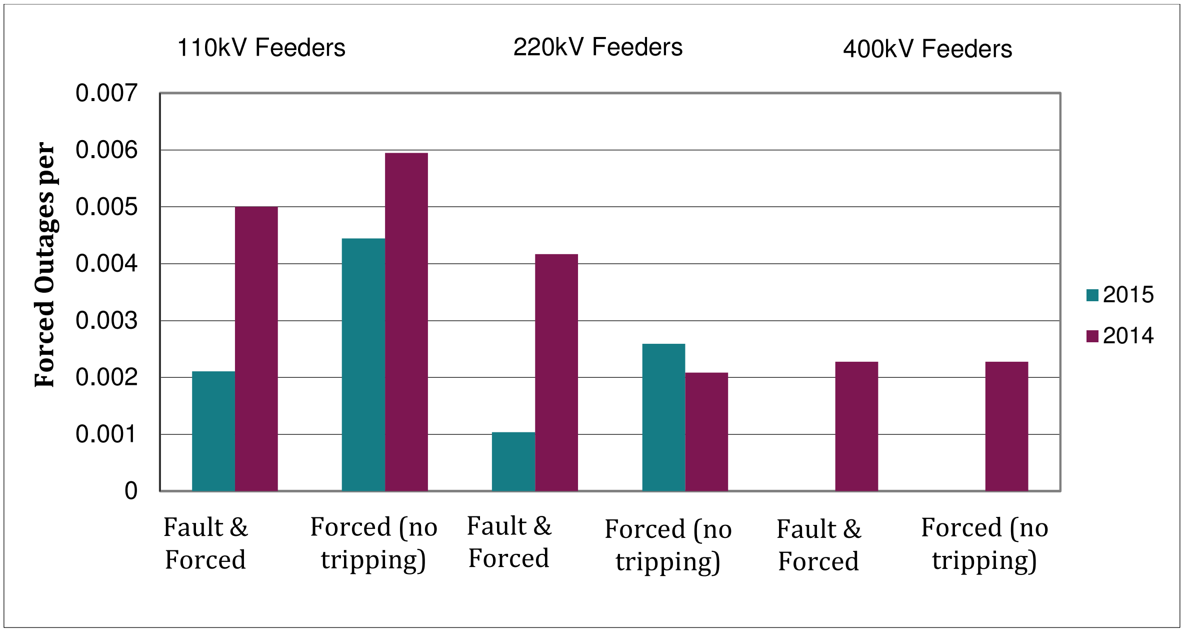
Fault & Forced
This occurs when an item of plant is tripped by protection and does not return to service within ten minutes. This typically signifies plant damage, which requires maintenance.

Forced (No Tripping)
This type of outage occurs when an item of plant is not tripped by protection, but is removed from the system urgently (i.e. there is no opportunity for scheduling). This may be necessary to avoid imminent failure or danger to plant and/or personnel. A typical cause of this outage would be the discovery of a fault during a maintenance inspection which is deemed to be sufficiently severe as to warrant the removal of the plant from service until the plant can be repaired or replaced.

4.6.12 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. This is shown in Figure 15; fault & reclose forced outages are excluded due to their relatively low level of disruption.

Figure 15: Nature of Feeder Forced Outages 2014 & 2015

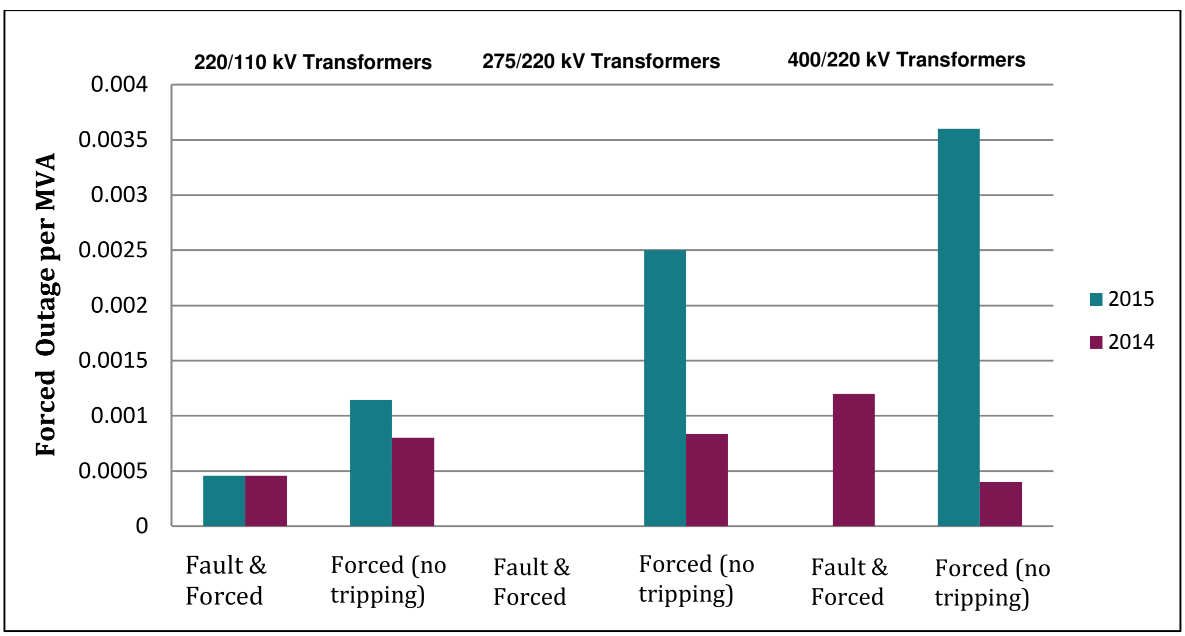


4.6.13 Forced Outages per MVA

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.

There was an overall increase in forced outages per MVA for 2015. There were no major forced outage incidents in 2015. The increase is down to an increase in alarms, mainly low SF6 and low CB pressure.

Figure 16: Nature of Transformer Forced Outages 2014 & 2015



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 2015 was 96.83 %. In 2015 the transmission system was significantly reconfigured at Tamnamore. The planned outages for the works at Tamnamore as well as the busbar refurbishment work at a number of substations led to a reduced system availability.

The annual availability of the Moyle Interconnector for 2015 was 49.62 %; although the interconnector has an installed capacity of 500 MW, its capacity has been limited to 250 MW since 2012 due to a cable fault. As of the 26 January 2016, Mutual Energy completed a project that restored the interconnector to its full availability, with an import limit of 450 MW and an export limit of 280 MW. An increase in availability of the Moyle Interconnector can be expected in 2016.

In terms of the connections between Northern Ireland and Ireland the North-South 275 kV tie line had an availability of 98% in 2015. The two 110 kV tie lines had an annual availability of 100 %.

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 2015, there were two transmission incidents leading to customers being off supply. These were;

- On the 30 April 2015 at 13:55, an incident at Castlereagh 275 kV substation resulted in the loss of supply to 204,680 customers. The system minutes lost for this event was 2.519.
- On the 23 June 2015, an incident at Ballymena 110 kV substation resulted in the loss of supply to 26,172 customers. The system minutes lost for this event was 0.087.

Quality of service is measured by the number of voltage and frequency excursions which fall outside statutory limits. There were no voltage excursions in 2015 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 are required to report on system faults where the frequency drops below 49.8 Hz or above 50.2 Hz. In 2015, there were 54 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

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 at less than seven days' notice.

System Availability is calculated using the formula:

Equation 1: System Availability Formula

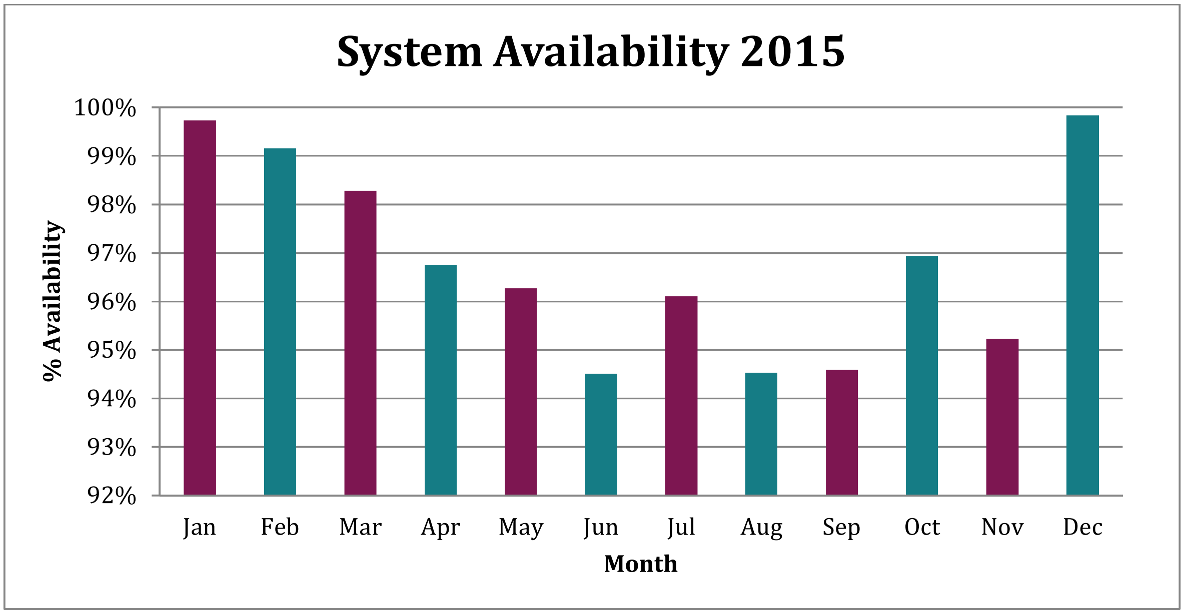
$$\text{Sytem Availability } (\%) = \frac{\sum \text{Hours each circuit is available}}{(\text{No. of Circuits}) * (\text{Total No. Hours in Period})}$$

In 2015, the analysis of the transmission system availability data has produced the following results:

- The average availability of the Northern Ireland transmission system was in 2015 was 96.83%,
- The average winter system availability (for the winter months January, February, November and December 2015) was 98.49%.

Figure 17 below shows the month by month variation in system availability of the transmission network in Northern Ireland.

Figure 17: Transmission System Availability 2015

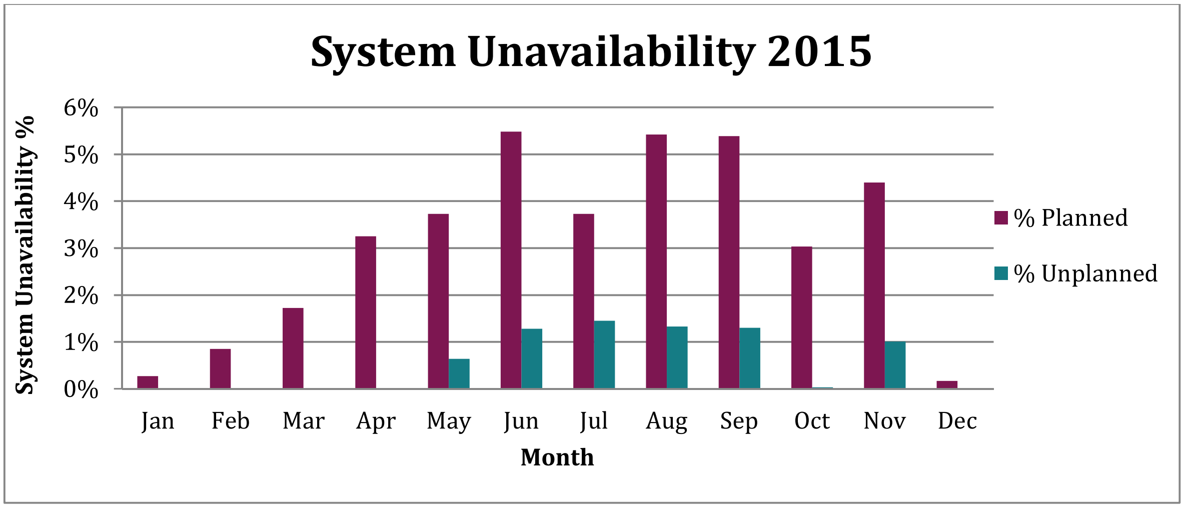


Overall, the availability of the system is high, particularly over the winter months where maintenance is avoided due to the higher electrical demand and potential adverse weather conditions. The preference is for maintenance to take place over the summer months when network loading is generally lower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

5.2.1 System Unavailability

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

Figure 18: Transmission System Unavailability 2015

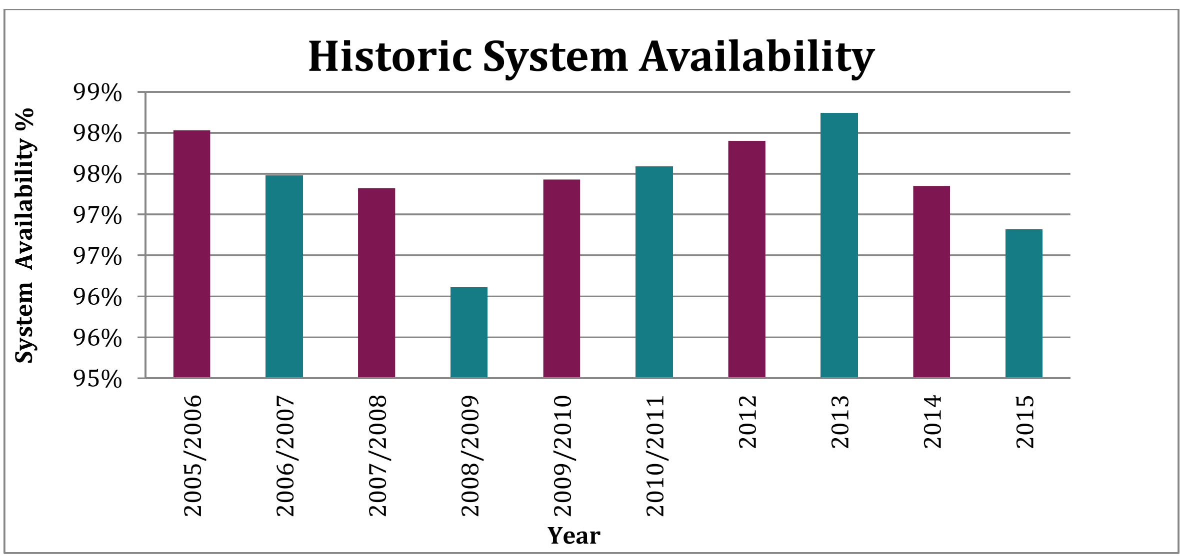


The majority of outages occurred during the spring/summer months. This reflects the policy of planning outages during periods of lower electrical demand.

5.2.2 System Historic Availability Performance

Figure 19 shows the historic variation in system availability from 1999 to 2015 for the transmission network in Northern Ireland.

Figure 19: Historic System Availability 1998-2015

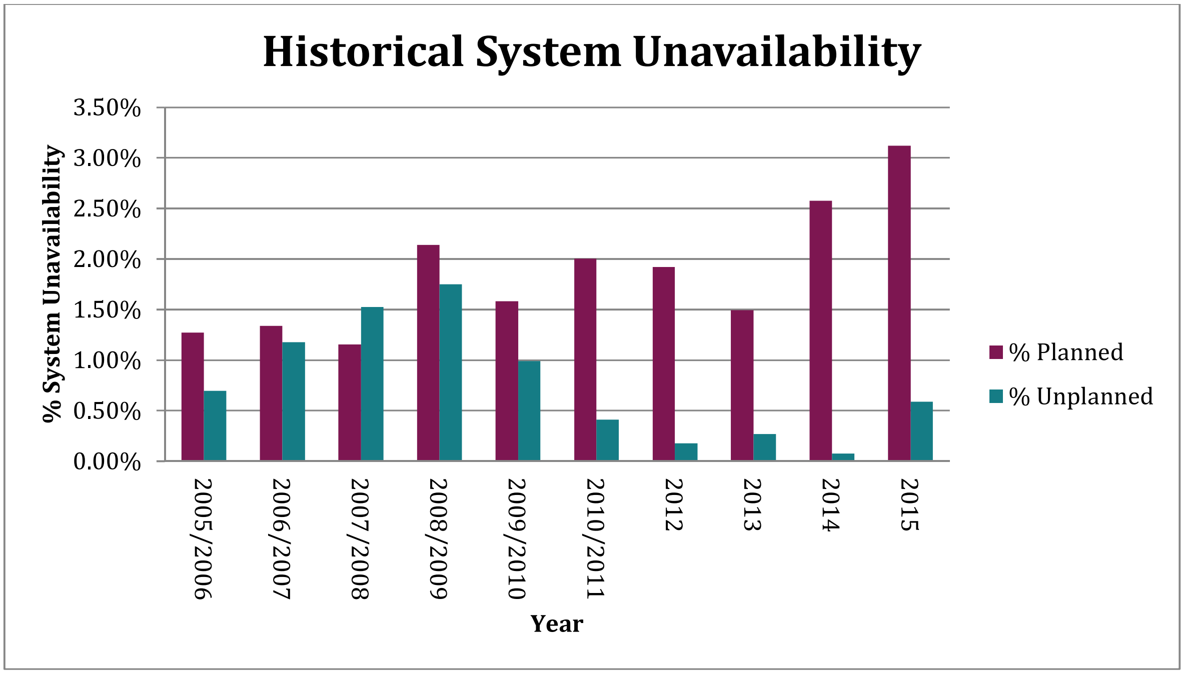


Prior to 2012, SONI calculated system availability in line with the company's financial year. This practice ended in 2012, in line with the practice in Eirgrid.

5.2.3 System Historic Unavailability Performance

Figure 20 below shows the breakdown of the system unavailability from 1999/2000 to 2015.

Figure 20: Historic System Unavailability 2005-2015



The 2015 average figure for system unavailability is higher compared to other years. 2015 saw an increase in the amount of work the NIE Networks carried out in new projects and maintenance work on the transmission network. Examples of this include;

- Tamnamore 110 kV Project
- 110 kV Substation Refurbishment works (Castlereagh, Kells, Tandragee 110 kV Substations)

5.3 Interconnector and Tie-Line Availability

5.3.1 Moyle Interconnector

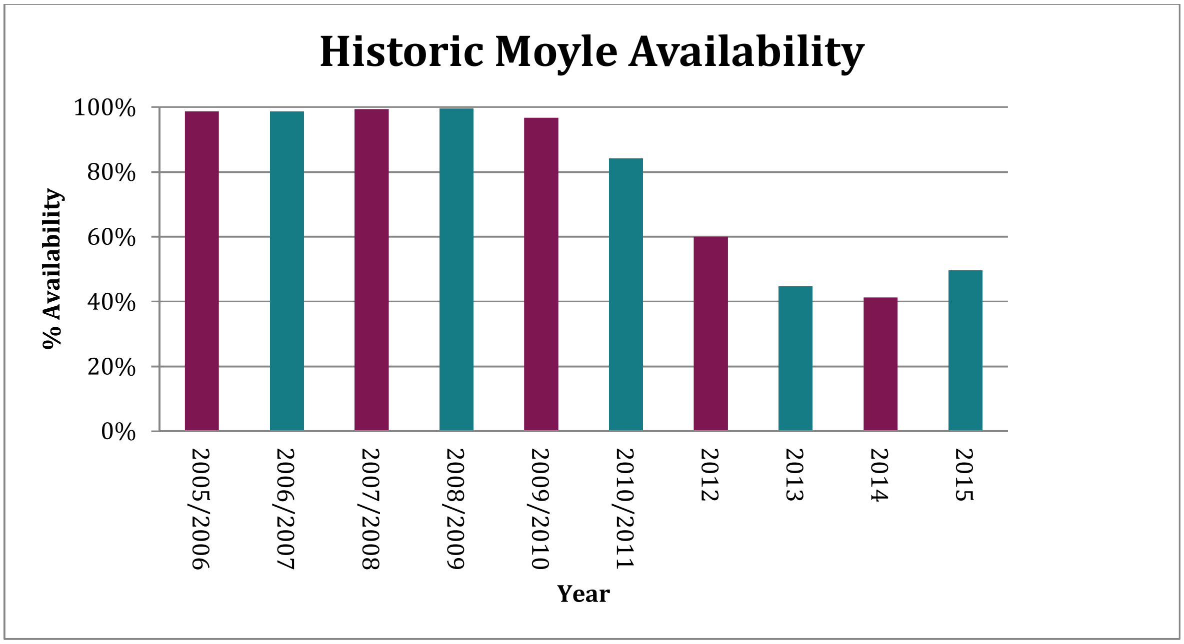
The Moyle interconnector, owned by Mutual Energy, connects the power systems of Northern Ireland and Scotland. The interconnector is a High Voltage Direct Current (HVDC) system; consisting of two submarine power cables and two HVDC-AC converter stations; one located at Islandmagee in Northern Ireland and the other at Auchencrosh in Scotland. The system has an import capacity of 450 MW and an export capacity of 280 MW. The interconnector is operated by SONI, and the performance of this link falls under the scope of this report.

In 2012, a cable fault occurred limiting the capacity of the interconnector to 250 MW. The asset owner, Mutual Energy, have been exploring the options available to them for restoring the interconnector to full capacity. A project is in place in the early part of 2016 to restore the interconnector to full capacity.

5.3.2 Moyle Interconnector Historic Availability

The Annual Availability of the Moyle Interconnector for 2015 was 49.62%.

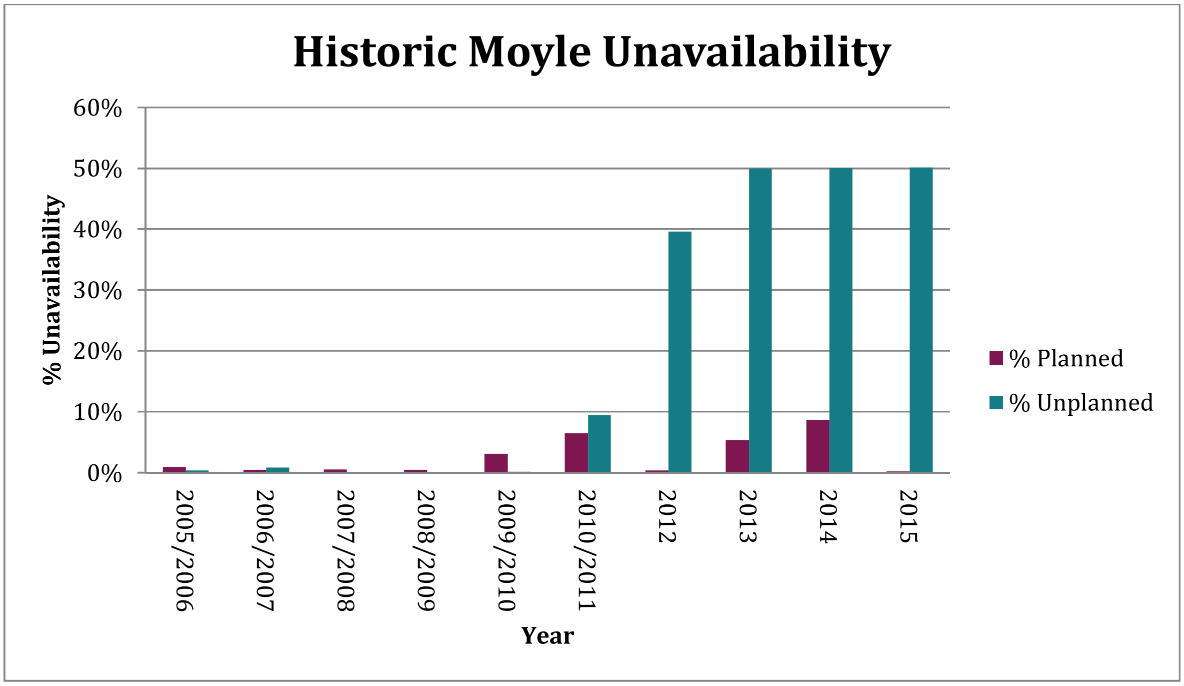
Figure 21: Historic Moyle Interconnector Availability 2002/03 - 2015



5.3.3 Moyle Interconnector Historic Unavailability

The 2015 Annual Unavailability of the Moyle Interconnector was 50.38%.

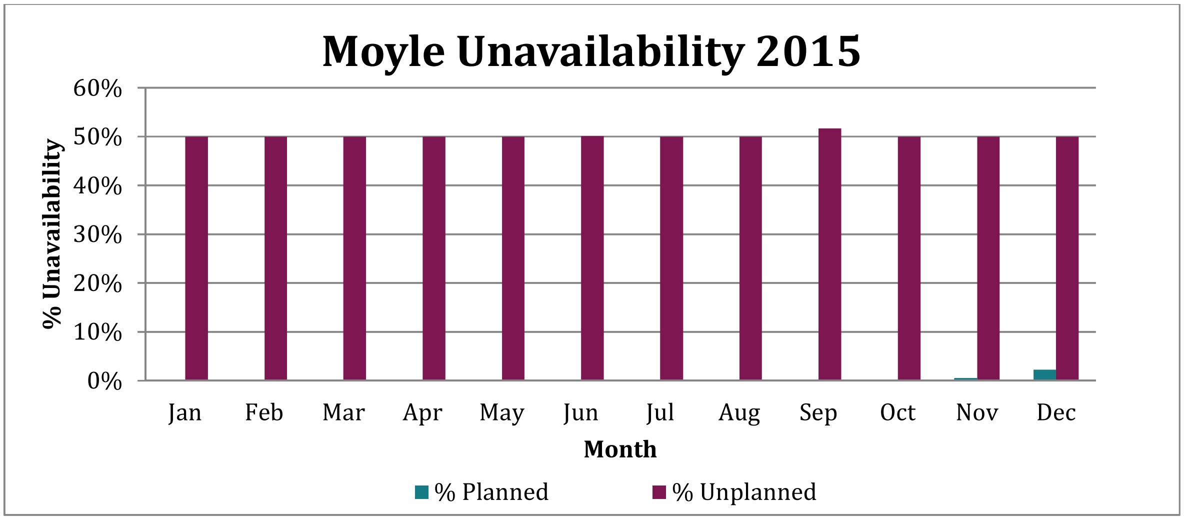
Figure 22: Historic Moyle Interconnector Unavailability 2005-2015



5.3.4 Moyle Interconnector Monthly Unavailability

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

Figure 23: Moyle Interconnector Unavailability 2015



Outages were required by the asset owner in the latter months of the year as part of a project to return the interconnector to full capacity. The asset owner, Mutual Energy, completed a project to install new low voltage submarine cables in parallel with the existing cables. These LV cables form key components in the make-up of the HVDC system.

5.3.5 275 kV Tie Line

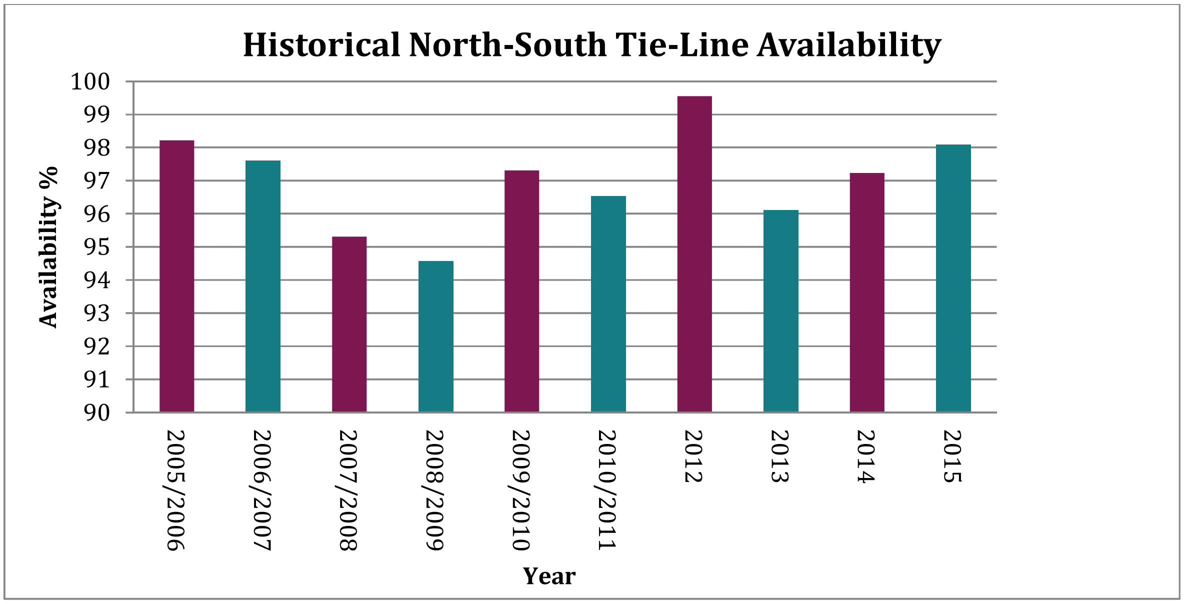
The Northern Ireland transmission system is connected to the transmission system in Ireland by means of one 275 kV double circuit connection from Tandragee 275 kV substation in Co. Armagh to Louth 220 kV substation in Co. Louth.

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

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.

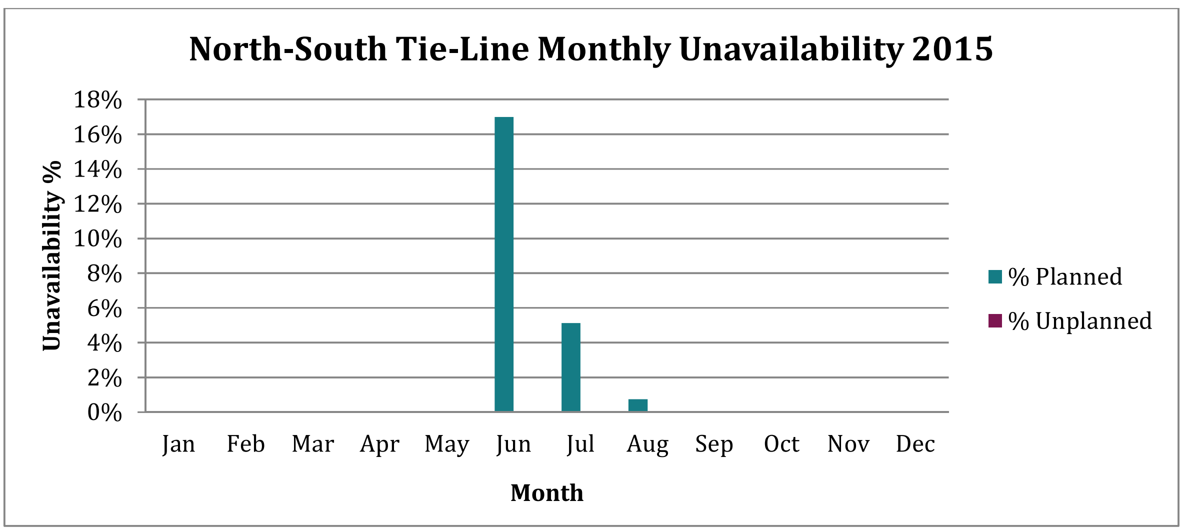
The annual availability of the 275kV North-South Tie Line in 2015 was 98.09%.

Figure 24: Historic North-South Tie Line Availability 1995-2015



Month by month variation of unavailability of the North-South Tie Line can be seen below.

Figure 25: North-South Tie Line Monthly Unavailability 2015



5.3.6 110 kV Tie Lines

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

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

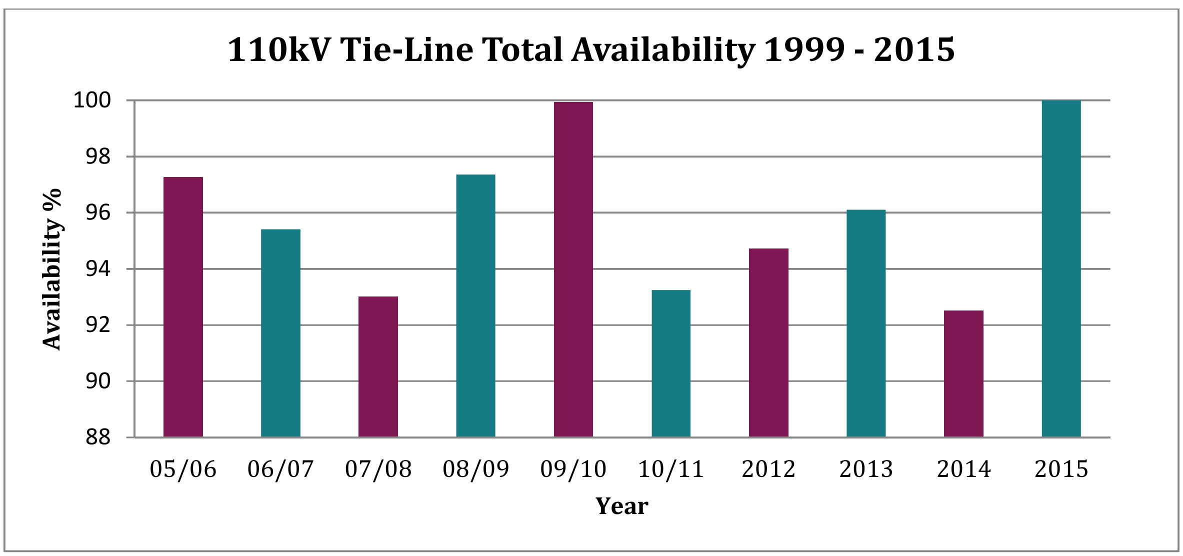
These 110 kV tie lines provide an AC connection between the two transmission systems, which allows emergency flows of active and reactive power for frequency and voltage support, increasing system stability.

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 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.

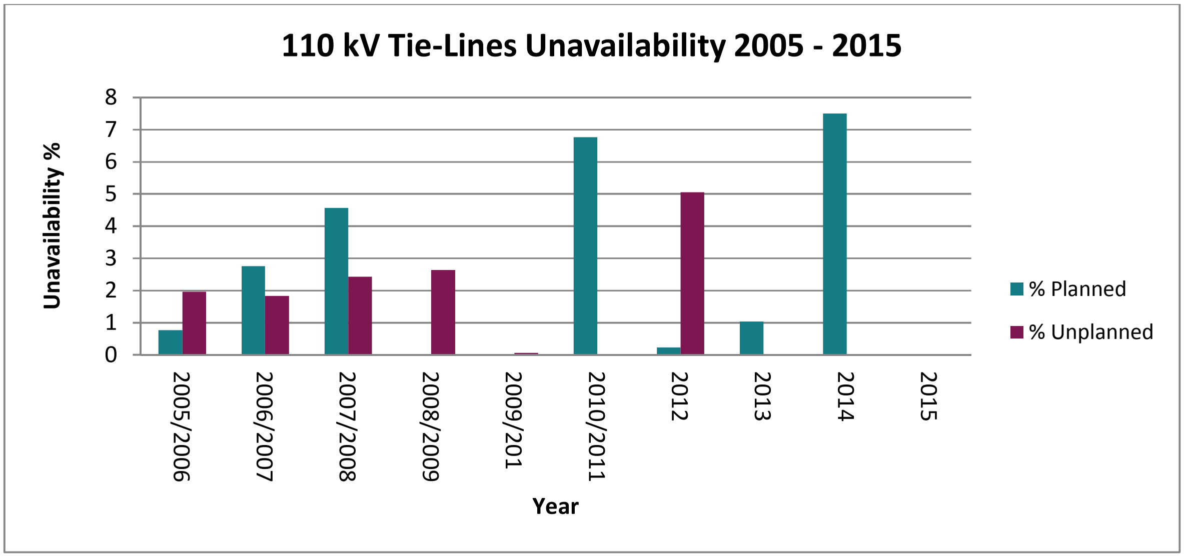
The availability of the 110 kV Tie Lines was 100 % for 2015. Maintenance carried out in 2014 contributed to this level of availability.

Figure 26: North-South Tie Line Unavailability 1995-2015



A breakdown of 110 kV tie line unavailability is shown in Figure 27 below.

Figure 27: Historic 110kV Tie Line Availability 1999-2015



5.4 Transmission System Security

An incident is a system event that results in loss of supply. 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.

5.4.1 Incidents for 2015

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.

5.4.2 Number of Incidents and Estimated Unsupplied Energy

There were two system events in Northern Ireland that resulted in the loss of supply to customers.

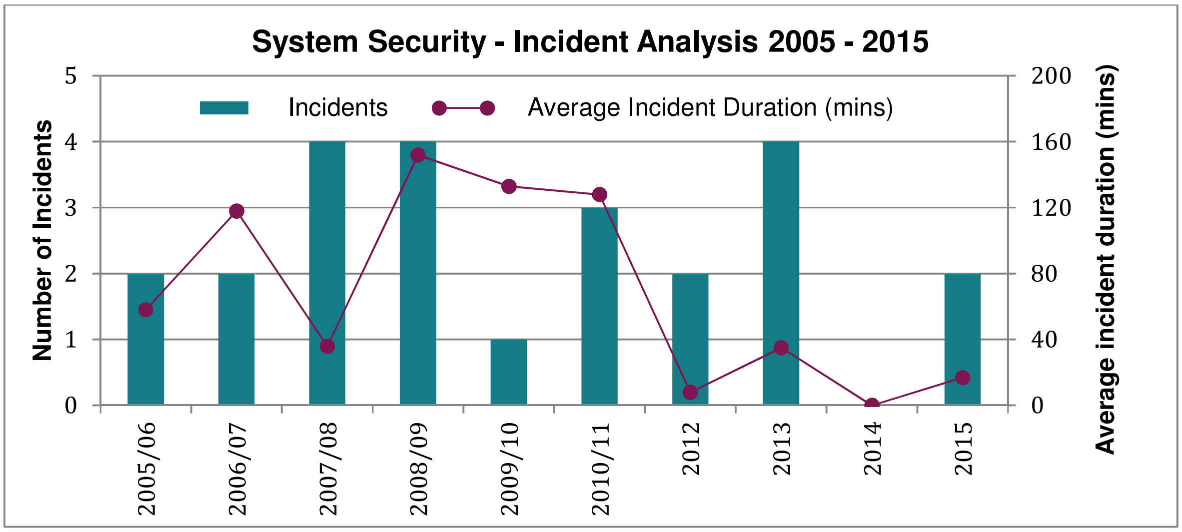
On the 30th of April 2015, an event occurred at Castlereagh 110 kV substation that resulted in the loss of 204,860 customers, equating to a total loss of 217 MW. All customers were fully restored within 28 minutes of the event happening,

On the 23rd of June 2015, a system event occurred at Ballymena Main substation that resulted in the loss of 26,172 customers, equating to a total loss of 26 MW. All customers were fully restored within 6 minutes of the event happening.

5.4.3 Incident Analysis

Figure 28 details the incidents that have occurred historically in Northern Ireland.

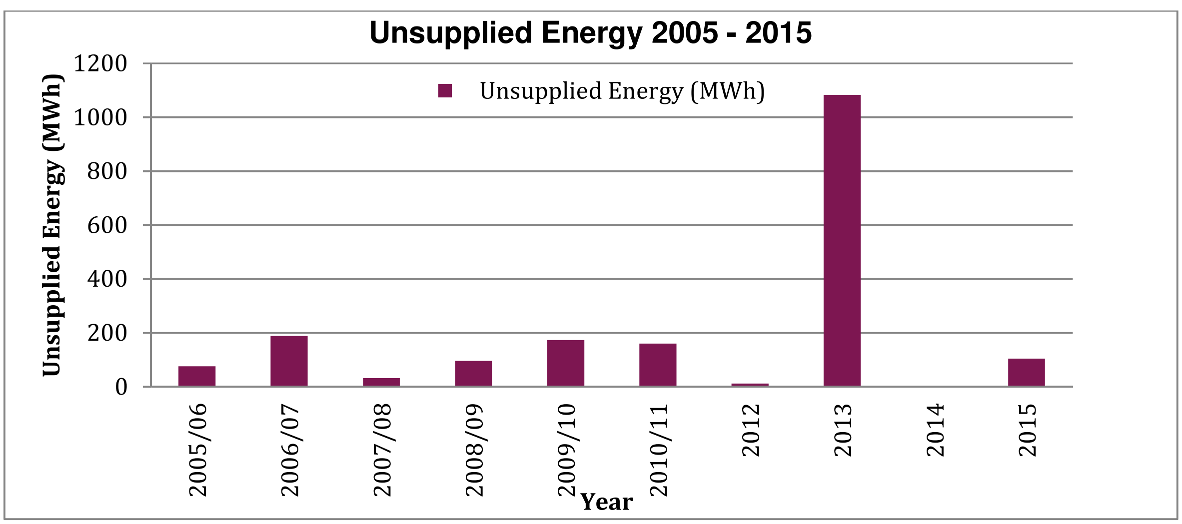
Figure 28: Historic System Security 1995-2015



5.4.4 Unsupplied Energy

Figure 29 below shows the historic amount of unsupplied energy to Northern Ireland customers.

Figure 29: Historic Unsupplied Energy 2005-2015



5.5 Quality of Service

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

5.5.1 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 operate the transmission system in such a way as to comply with the Operating Security Standards[6], acceptable step changes in voltages are detailed in Table 14.

Table 14: 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%

5.5.2 Voltage Excursions

There were no voltage excursions exceeding these limits in 2015.

5.5.3 Frequency

SONI are 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 14 reportable frequency excursions in Northern Ireland in 2015. Graphs in Appendix 2 contain traces of system frequency as well as raw and averaged rate of change of frequency data.

[6] SONI Operating Security Standards

5.5.4 Frequency Excursions

Table 15: Frequency Excursions in NI in 2015

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			
EWIC & B21	22/06/2015	08:56:26	524+113	50.010	49.086	49.086	-0.65	-0.31	111.9	52.7	-151
Great Island 4	07/07/2015	13:52:43	344	49.963	49.276	49.305	-0.46	-0.3	9.1	7.2	-42
Great Island 4	14/03/2015	16:51:30	470	49.997	49.306	49.391	-0.41	-0.35	6.4	5.1	-230
Great Island 4	06/01/2015	17:21:49	472	49.990	49.378	49.410	-0.42	-0.32	6.9	5.1	-142
Great Island 4	31/08/2015	17:17:51	420	50.033	49.419	49.480	-0.38	-0.31	5.5	3.8	16
Great Island 4	10/02/2015	15:44:10	404	50.008	49.477	49.504	-0.34	-0.24	5.2	2.2	-77
Huntstown 2	27/07/2015	08:31:18	320	49.950	49.482	49.582	-0.34	-0.22	4.2	1.7	-165
Great Island 4	31/03/2015	15:10:29	420	50.092	49.493	49.791	-0.39	-0.32	2.8	0.5	0
Great Island 4	04/03/2015	10:19:42	328	50.004	49.55	49.624	-0.28	-0.21	3.2	0	164
Great Island 4	18/03/2015	12:47:56	470	50.086	49.558	49.717	-0.38	-0.26	2.4	0	-3
Dublin Bay	22/01/2015	15:41:57	380	50.018	49.563	49.648	-0.3	-0.21	2.6	0	2
EWIC	20/06/2015	12:55:47	290	49.985	49.563	49.605	-0.29	-0.18	2.9	0	-63
Great Island 4	13/03/2015	20:30:53	477	50.117	49.581	49.780	-0.39	-0.27	1.5	0	-82
Moyle	07/08/2015	10:41:39	220	49.976	49.598	49.661	-0.38	-0.2	0.3	0	11

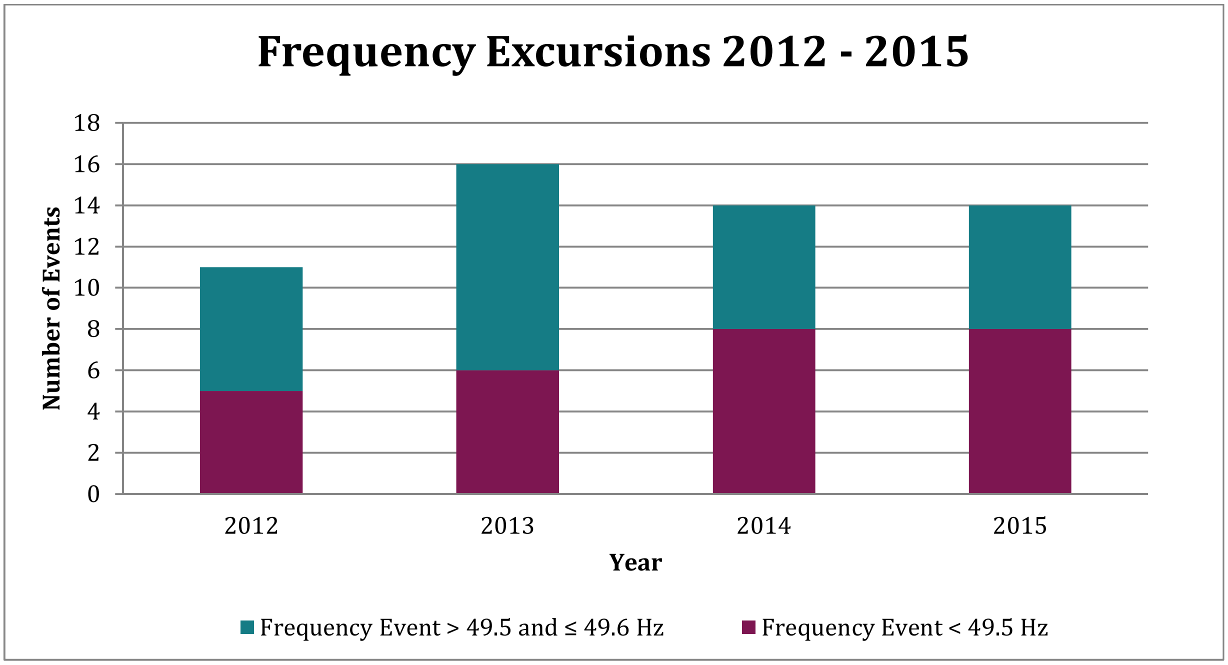
Note NS and Interconnection flows, +VE represents an import to Northern Ireland

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

5.5.5 Historical Frequency Excursions

Figure 30: Historic Frequency Excursions 2012-2015



Appendix 1 Glossary

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.

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.

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.

Main System

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 interconnector and 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 (ESB DSO load transformers, directly connected industrial customer load transformers and generator 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.

MVA Minute Lost

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

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 owned, SONI controlled, HV system in Northern Ireland.

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.

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.

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.

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.

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.

Sustained Interruption

A sustained interruption is one which lasts for more than one minute. For example, if a fault causes a supply interruption to demand customers and supply is not restored by reclosing the affected circuit breaker or by MV back feeding within one minute then this is classified as a sustained interruption. If supply is restored in less than one minute this is a non sustained interruption.

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.

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

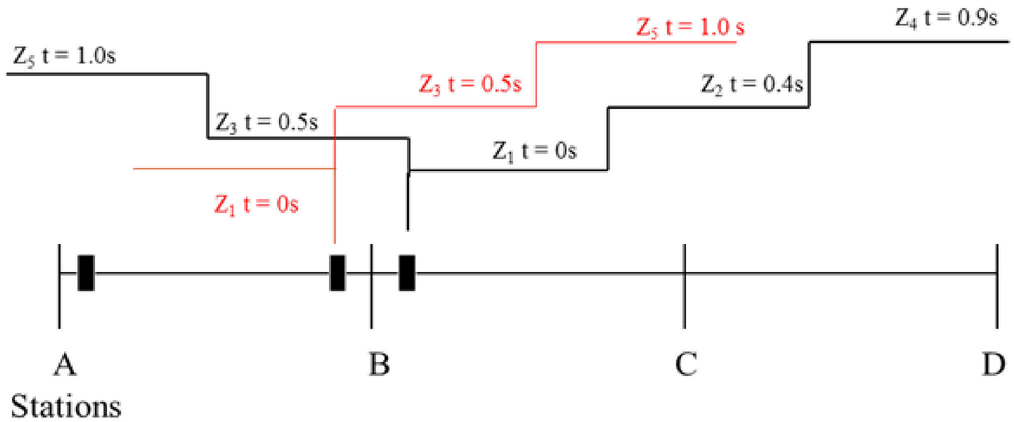
Transient Fault

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.

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.

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 4. 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.

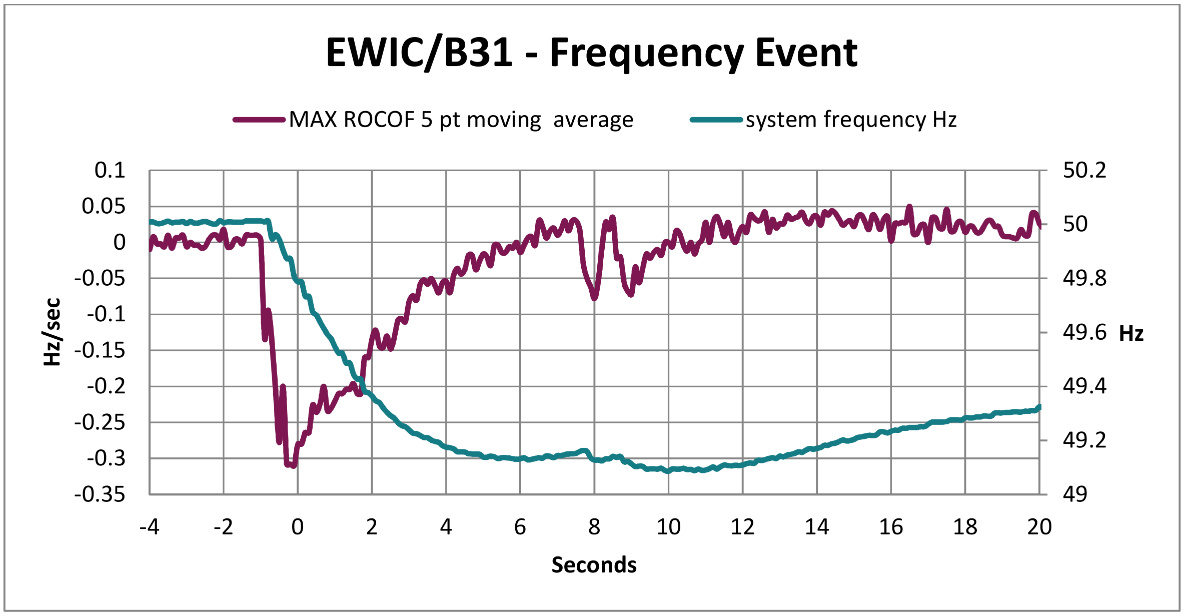
Zone 4 is the third forward step of a distance scheme with a time delay of approximately 900 ms.

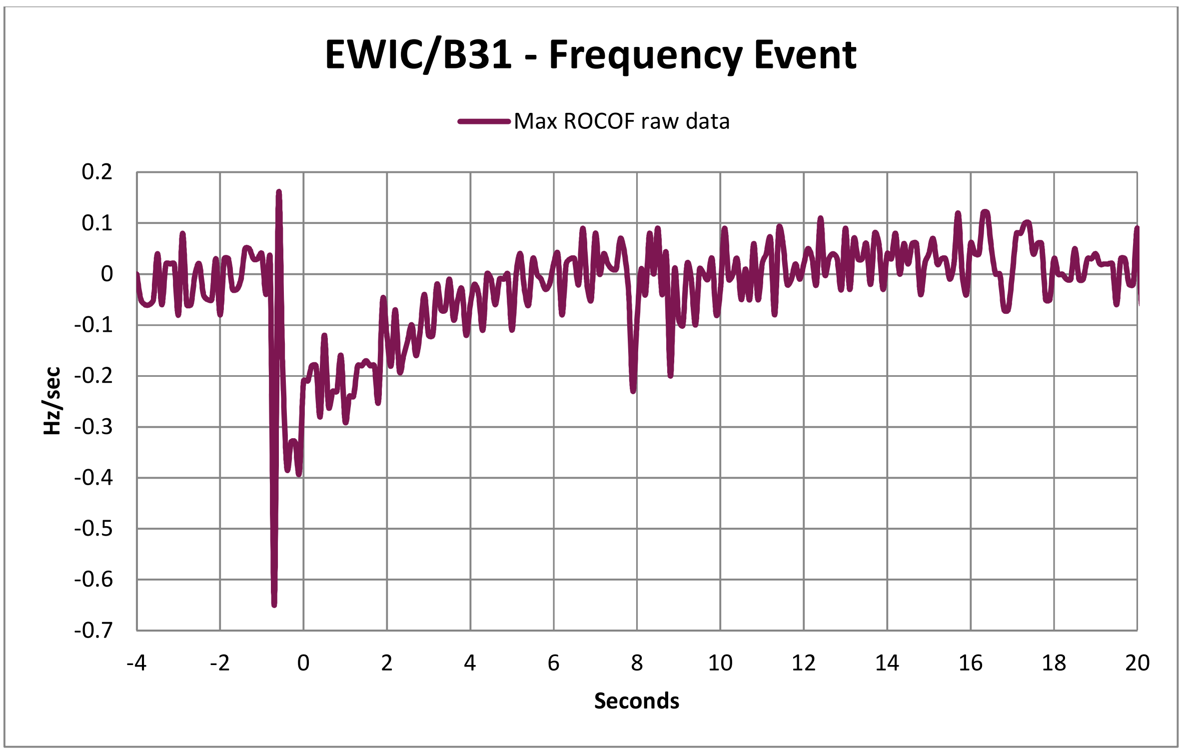
Zone 5 is the second reverse step of a distance protection scheme with a time delay of approximately 1 second.

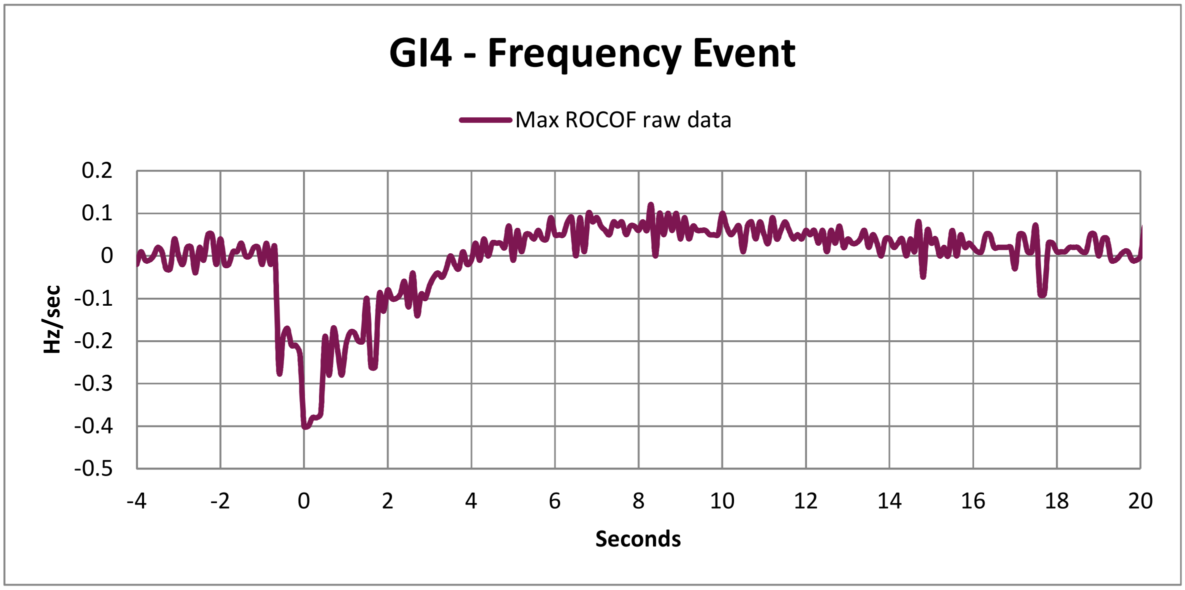
Zone 4 and 5 trips are very rarely initiated due to the in-built time delays.

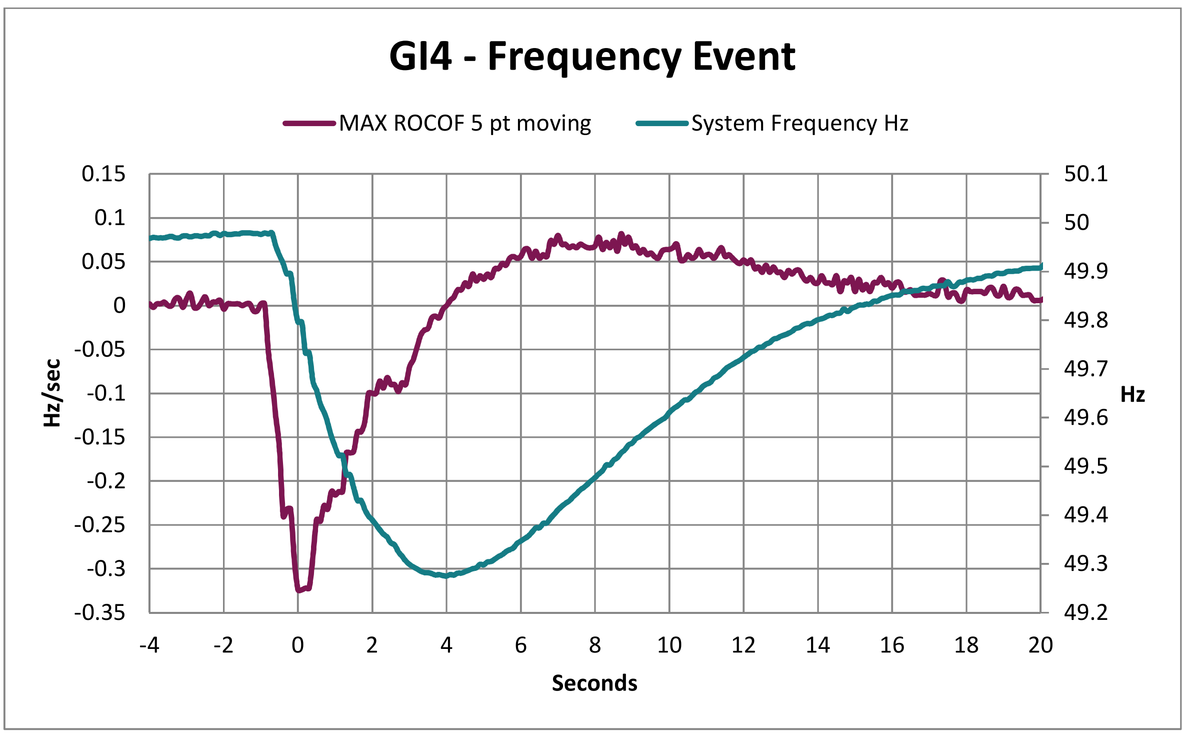
Appendix 2 All Island Frequency Excursion Graphs

Cause of Incident	Date
EWIC & B21	22/06/2015
Great Island 4	07/07/2015
Great Island 4	14/03/2015
Great Island 4	06/01/2015
Great Island 4	31/08/2015
Great Island 4	10/02/2015
Huntstown Unit 2	27/07/2015
Great Island 4	31/03/2015
Great Island 4	04/03/2015
Great Island 4	18/03/2015
Dublin Bay	22/01/2015
EWIC	20/06/2015
Great Island 4	13/03/2015
Moyle	07/08/2015

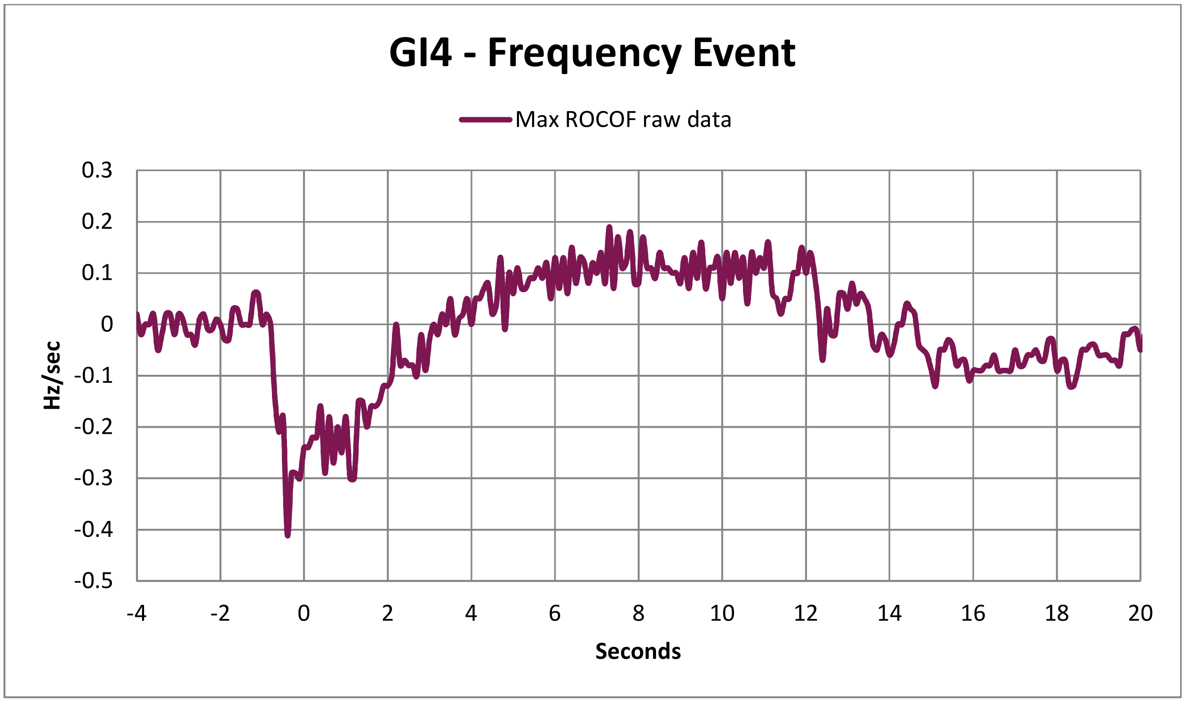

EWIC/B31 - Frequency Event
MAX ROCOF 5 pt moving average
system frequency Hz
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
-0.3
-0.35
Hz/sec
50.2
50
49.8
49.6
49.4
49.2
49
Hz
-4
-2
0
2
4
6
8
10
12
14
16
18
20
Seconds

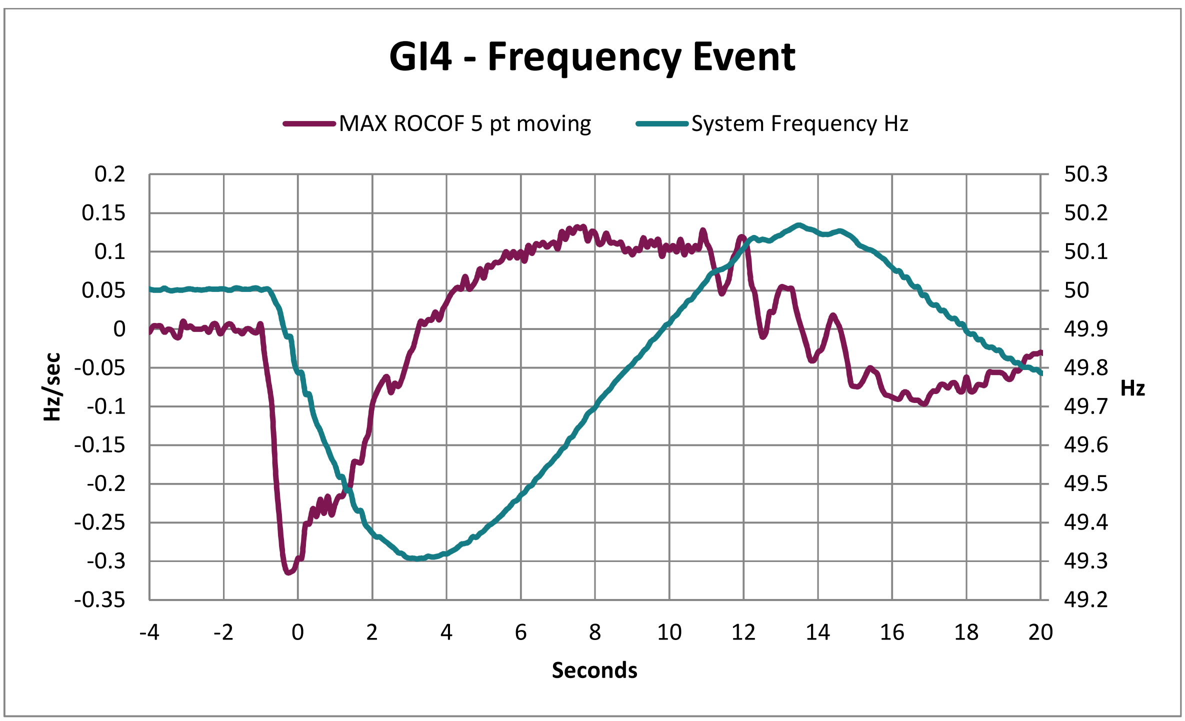

EWIC/B31 - Frequency Event
Max ROCOF raw data
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
Hz/sec
-4
-2
0
2
4
6
8
10
12
14
16
18
20
Seconds


GI4 - Frequency Event
Max ROCOF raw data
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
Hz/sec
-4
-2
0
2
4
6
8
10
12
14
16
18
20
Seconds

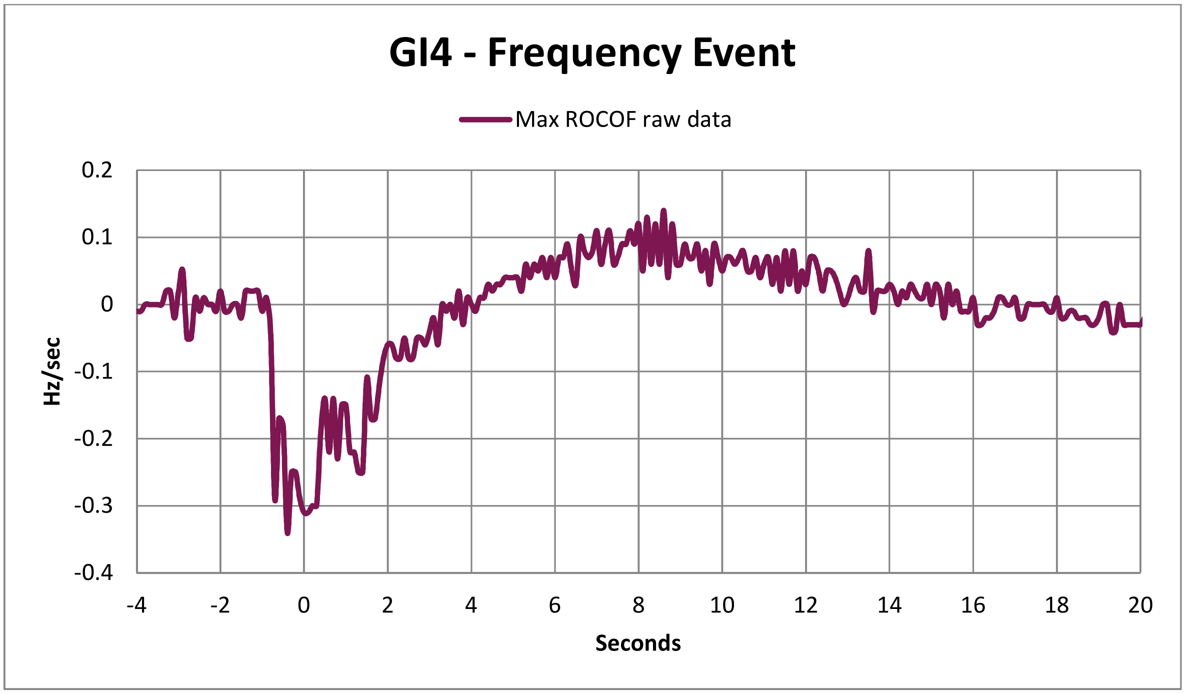

GI4 - Frequency Event
MAX ROCOF 5 pt moving
System Frequency Hz
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
-0.3
-0.35
Hz/sec
50.1
50
49.9
49.8
49.7
49.6
49.5
49.4
49.3
49.2
Hz
-4
-2
0
2
4
6
8
10
12
14
16
18
20
Seconds

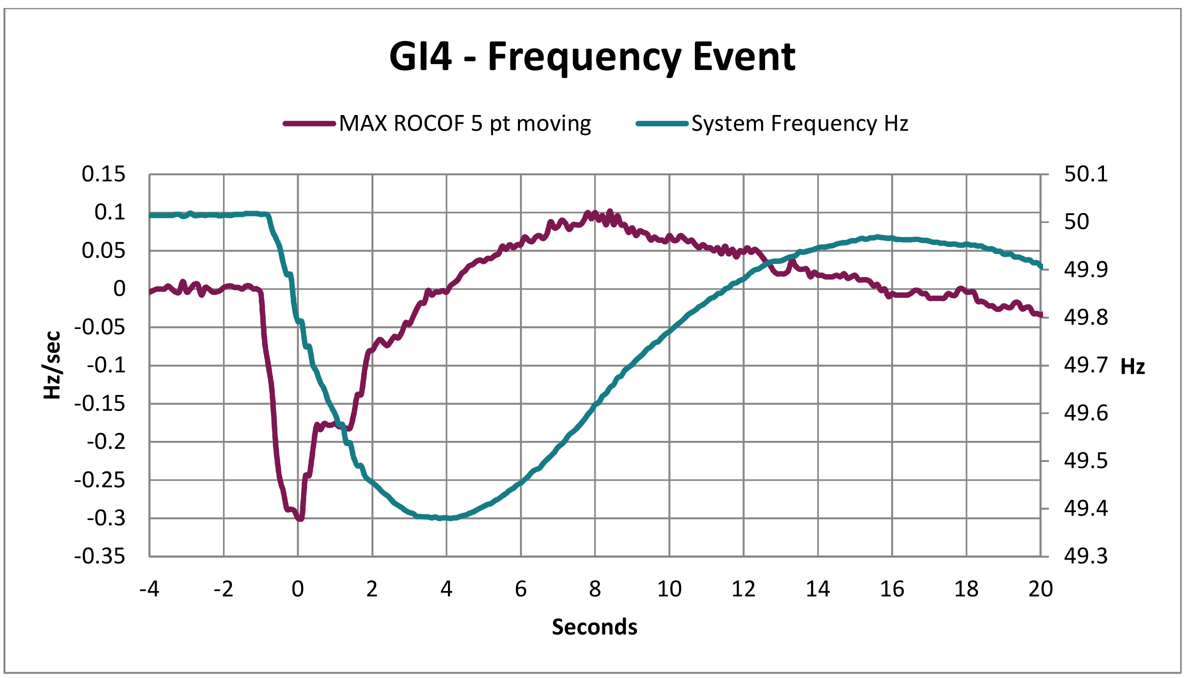
Great Island 4 – 14/03/2015

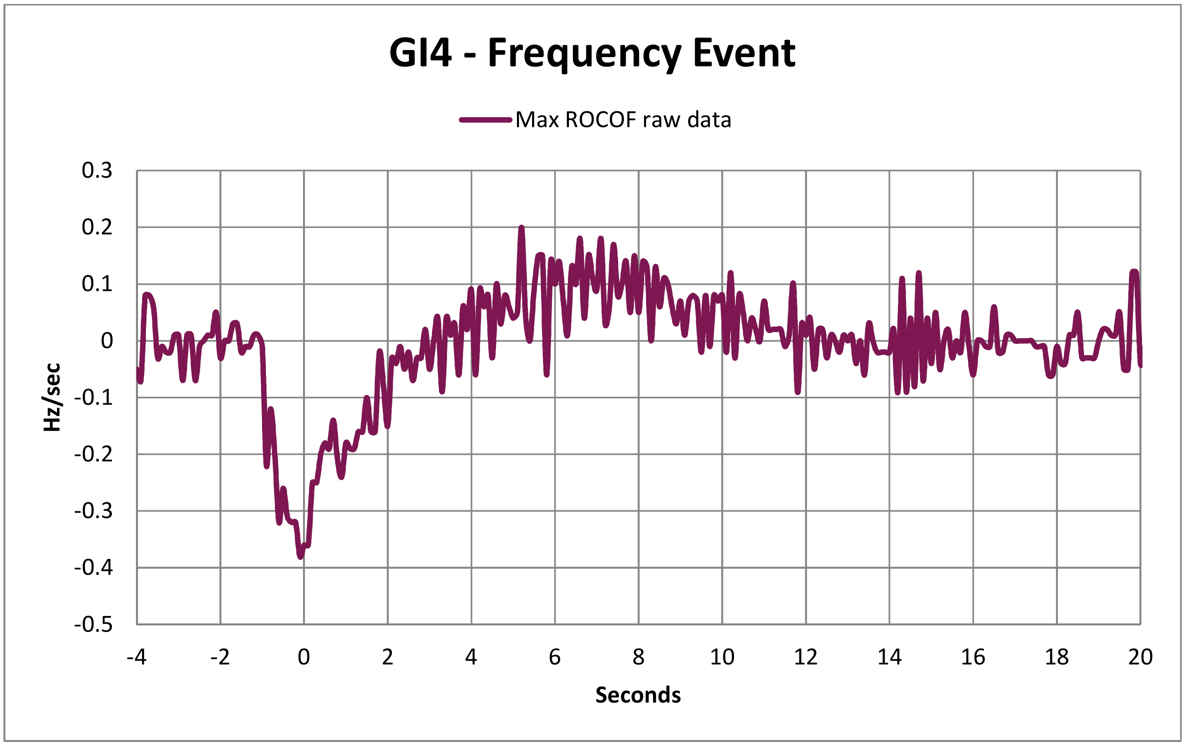


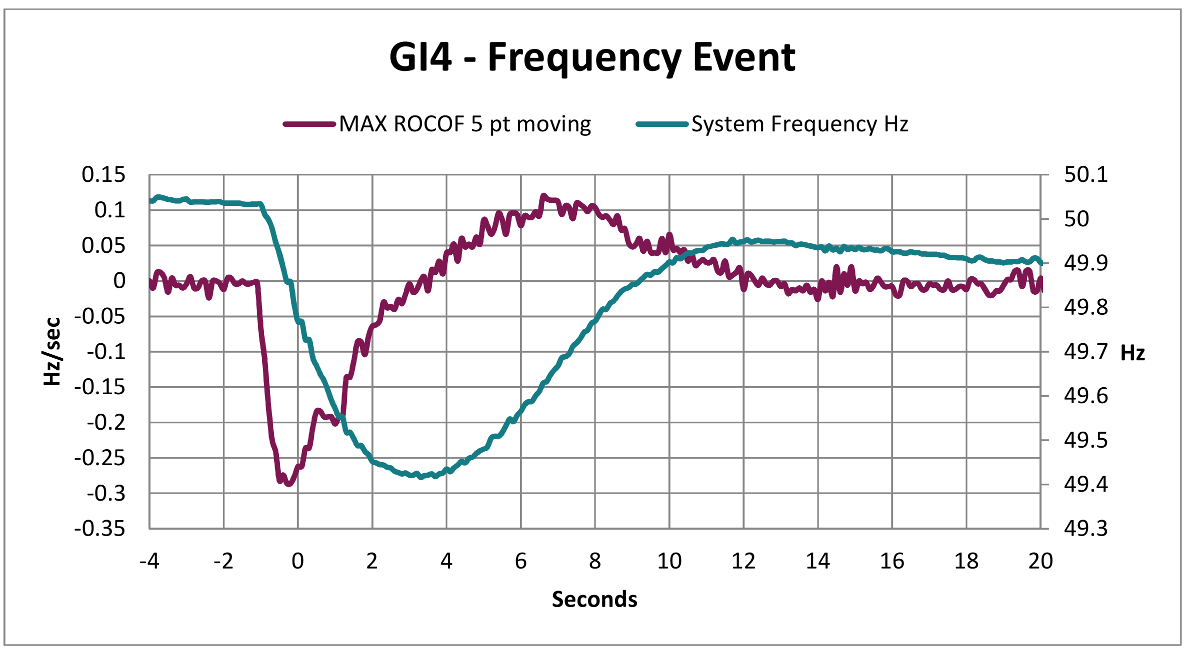


Great Island 4 – 06/01/2015

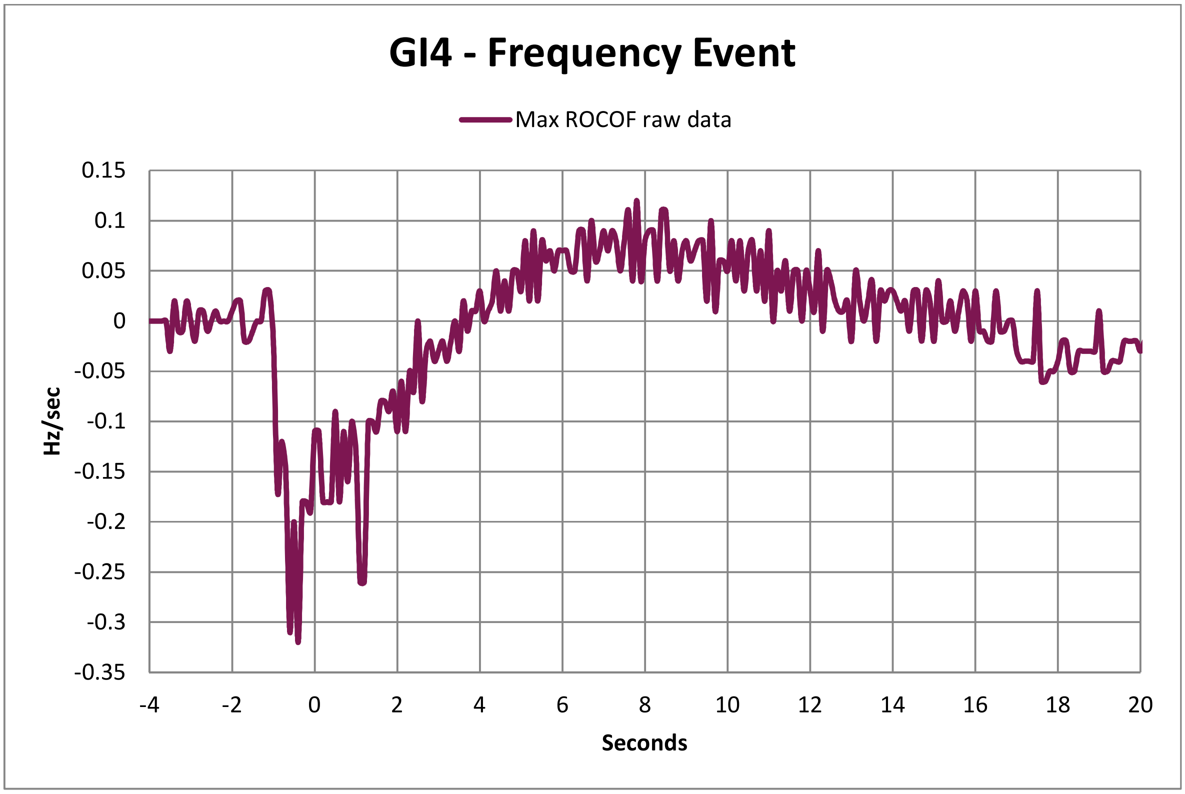


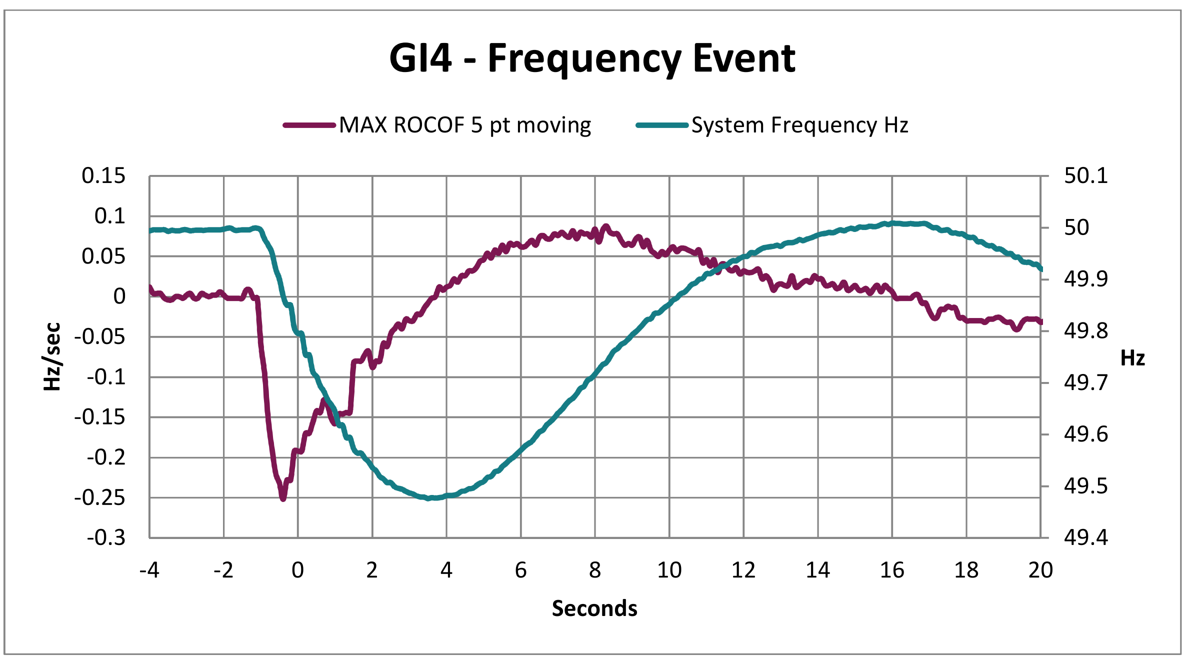



GI4 - Frequency Event
Max ROCOF raw data
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
Hz/sec
-4
-2
0
2
4
6
8
10
12
14
16
18
20
Seconds

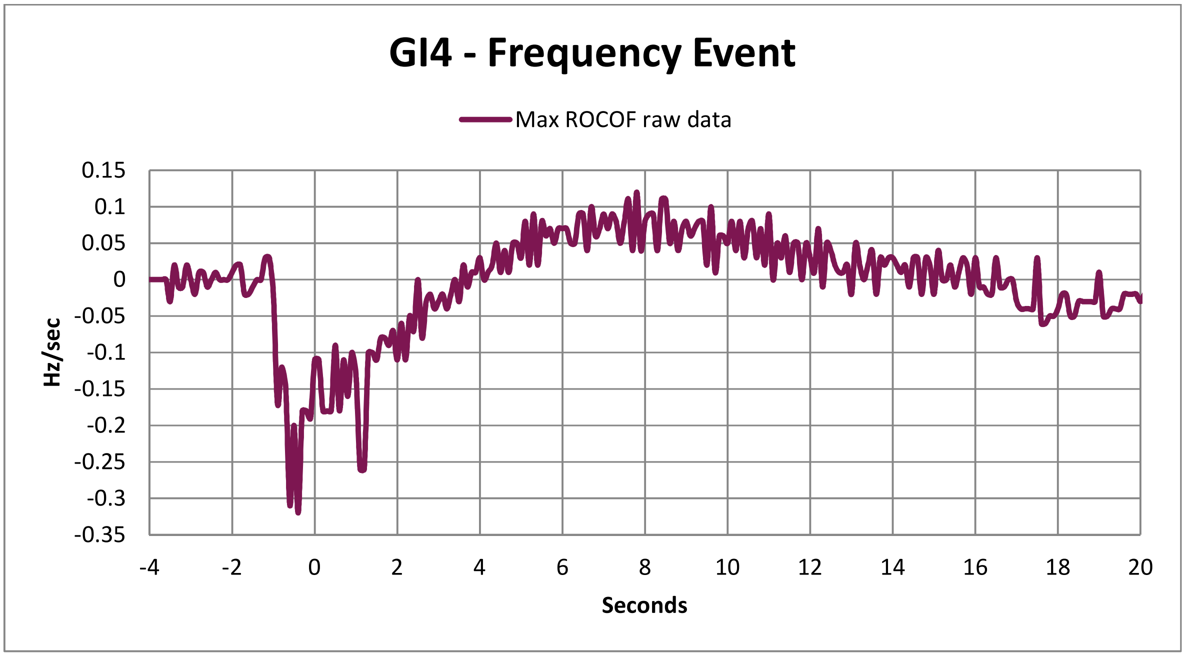

GI4 - Frequency Event
MAX ROCOF 5 pt moving
System Frequency Hz
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
-0.3
-0.35
Hz/sec
50.1
50
49.9
49.8
49.7
49.6
49.5
49.4
49.3
Hz
-4
-2
0
2
4
6
8
10
12
14
16
18
20
Seconds

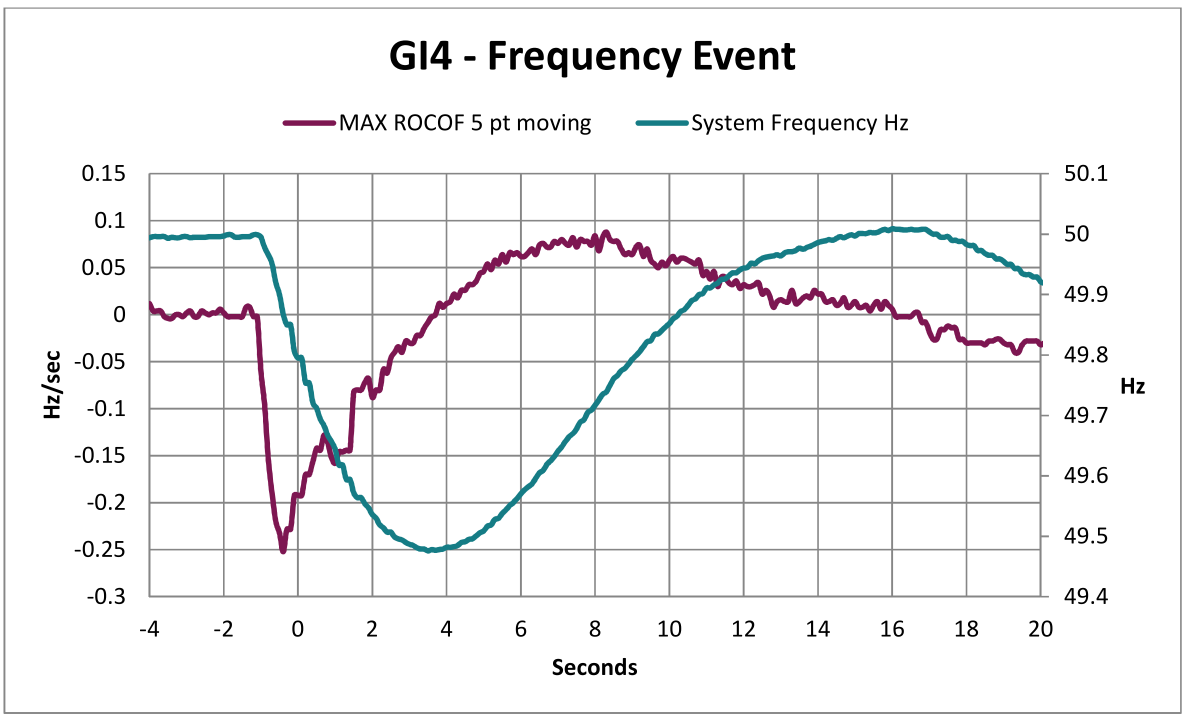
Great Island 4 – 10/02/2015



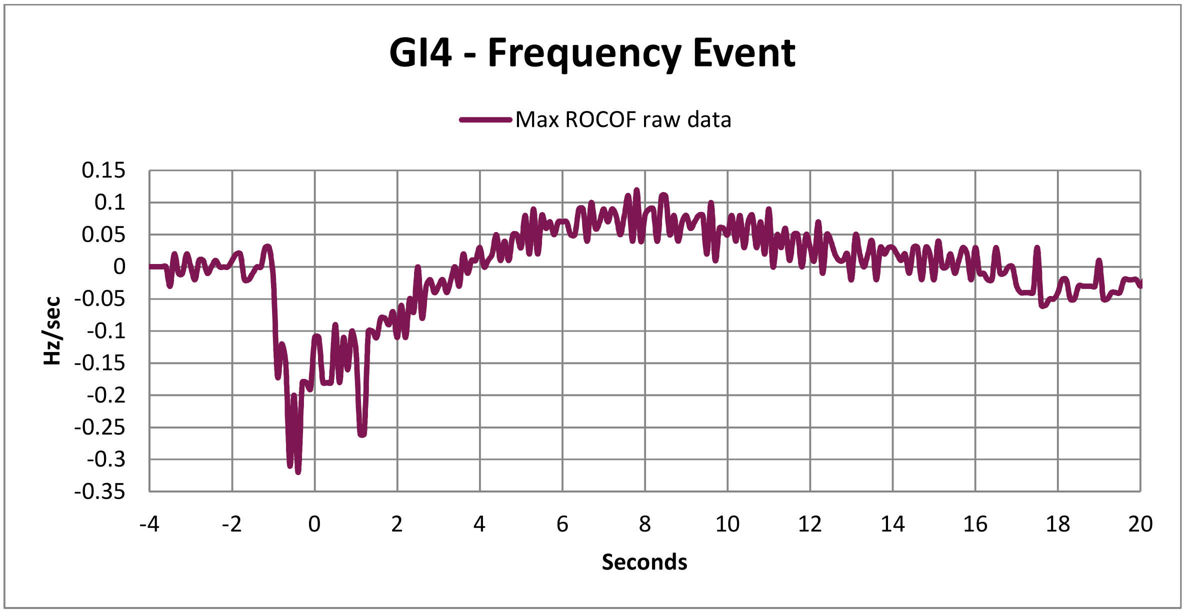


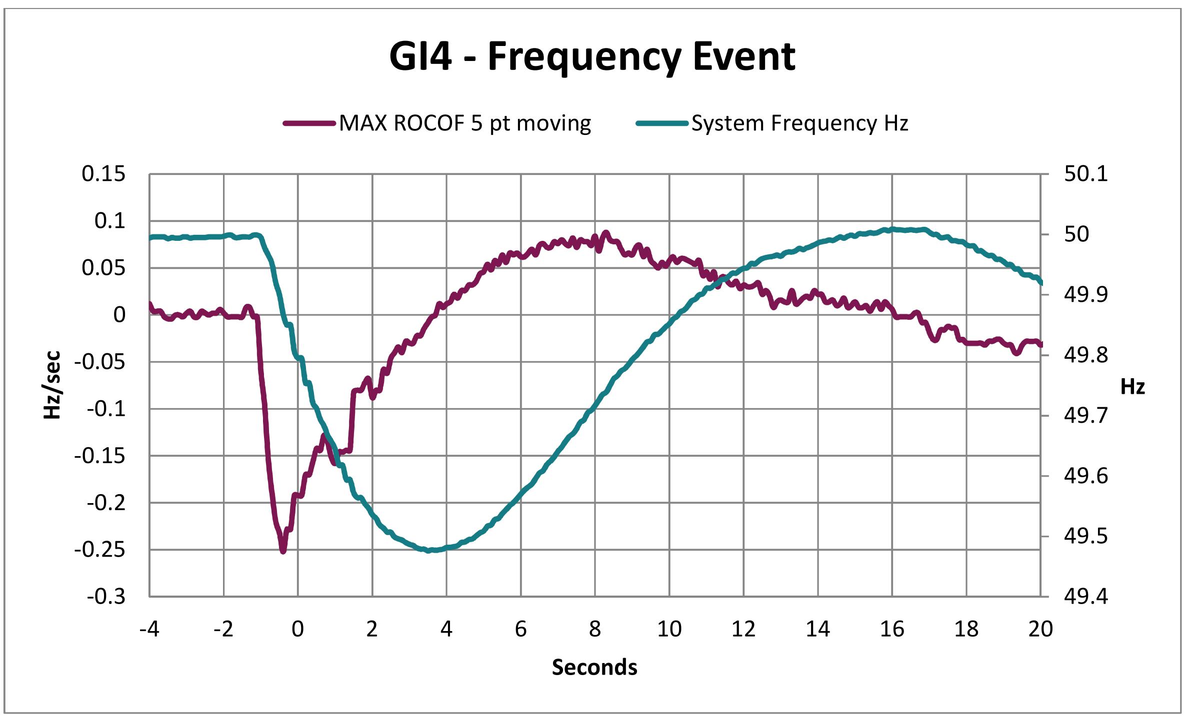
Huntstown Unit 2 – 27/07/2015



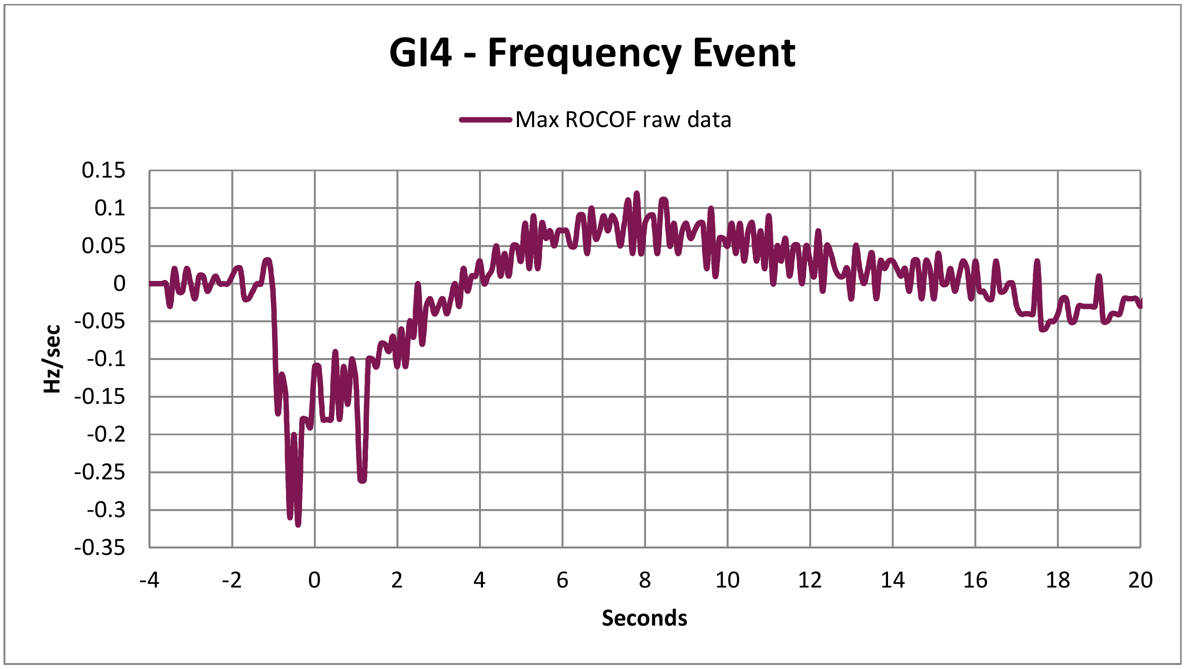


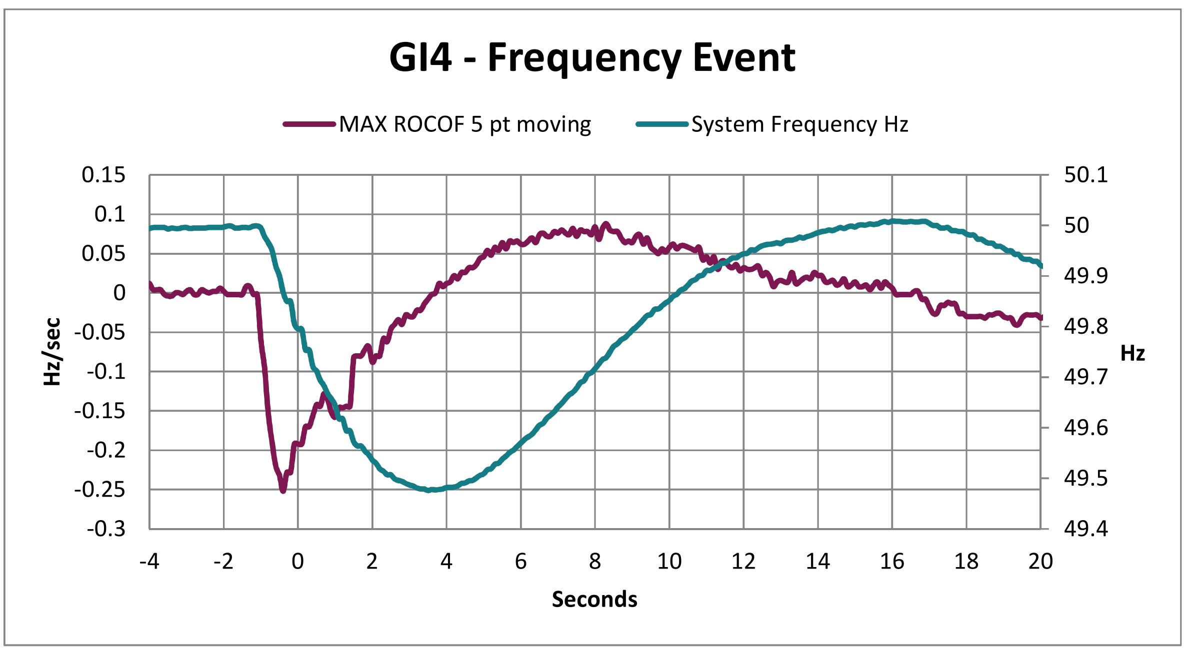
Great Island 4 – 31/03/2015



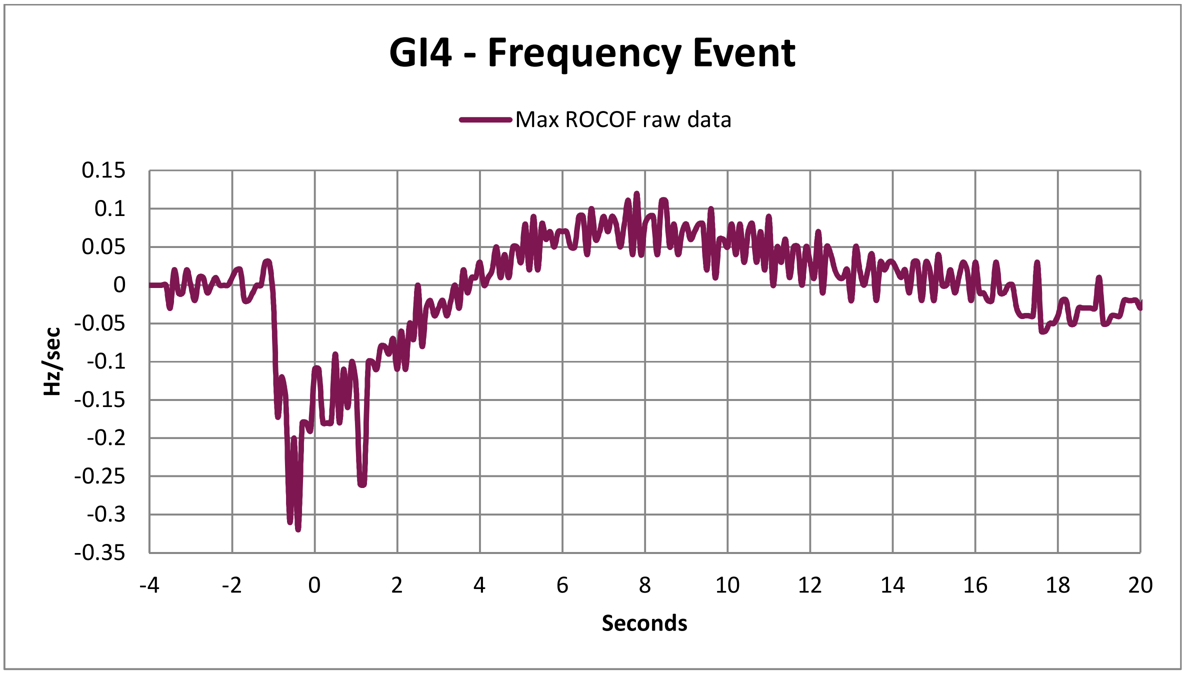


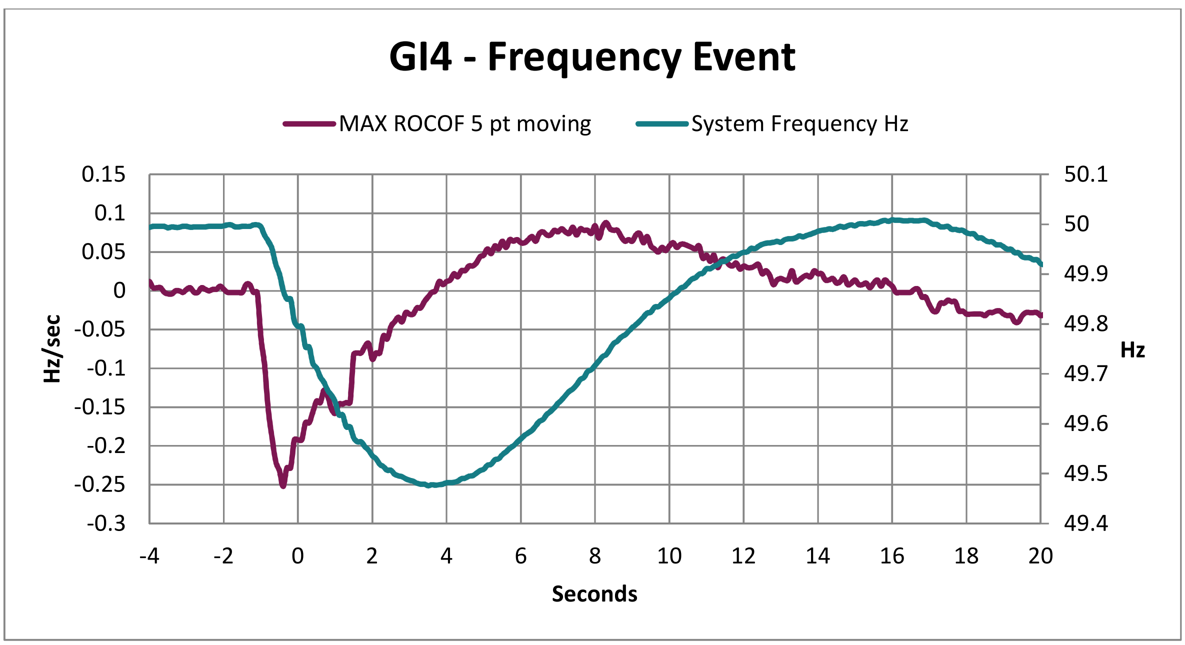
Great Island 4 – 04/03/2015



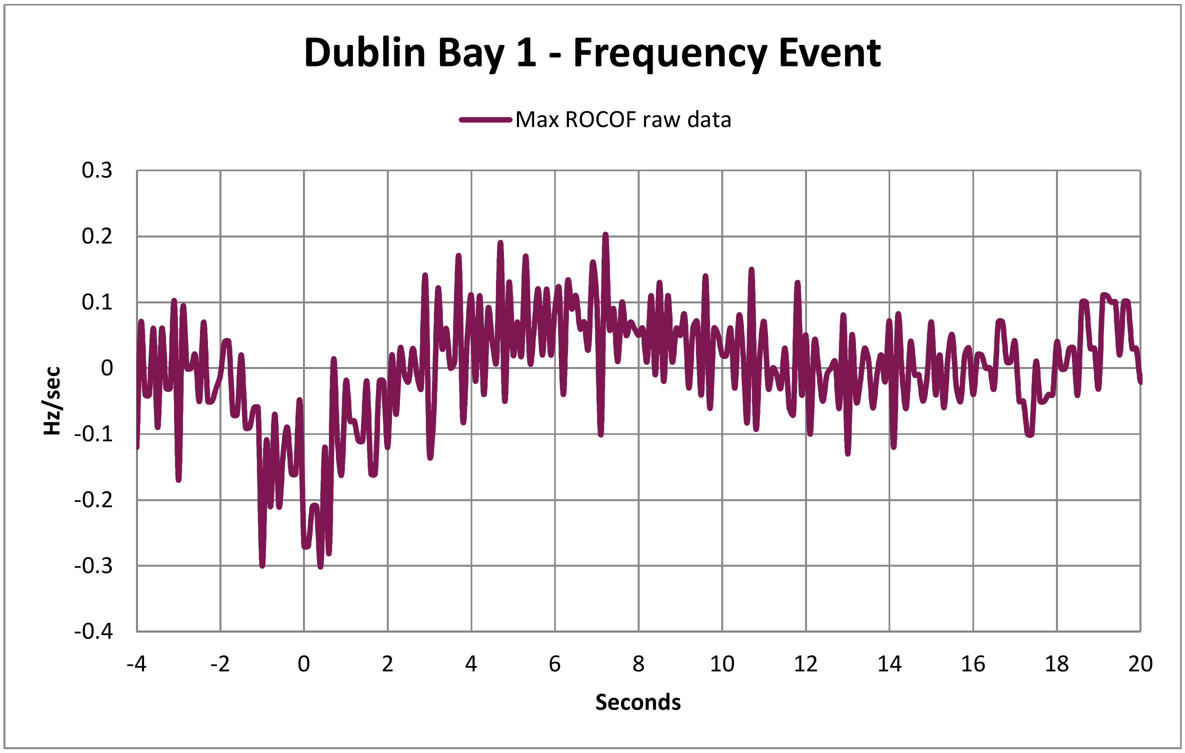


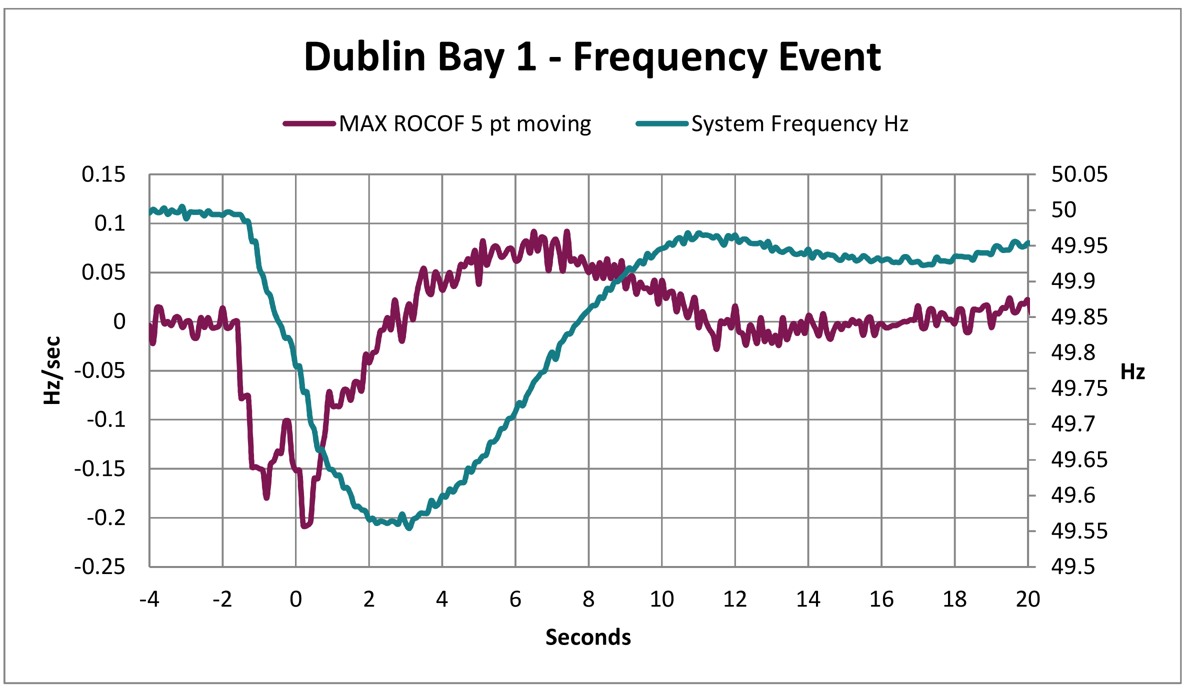
Great Island 4 – 18/03/2015

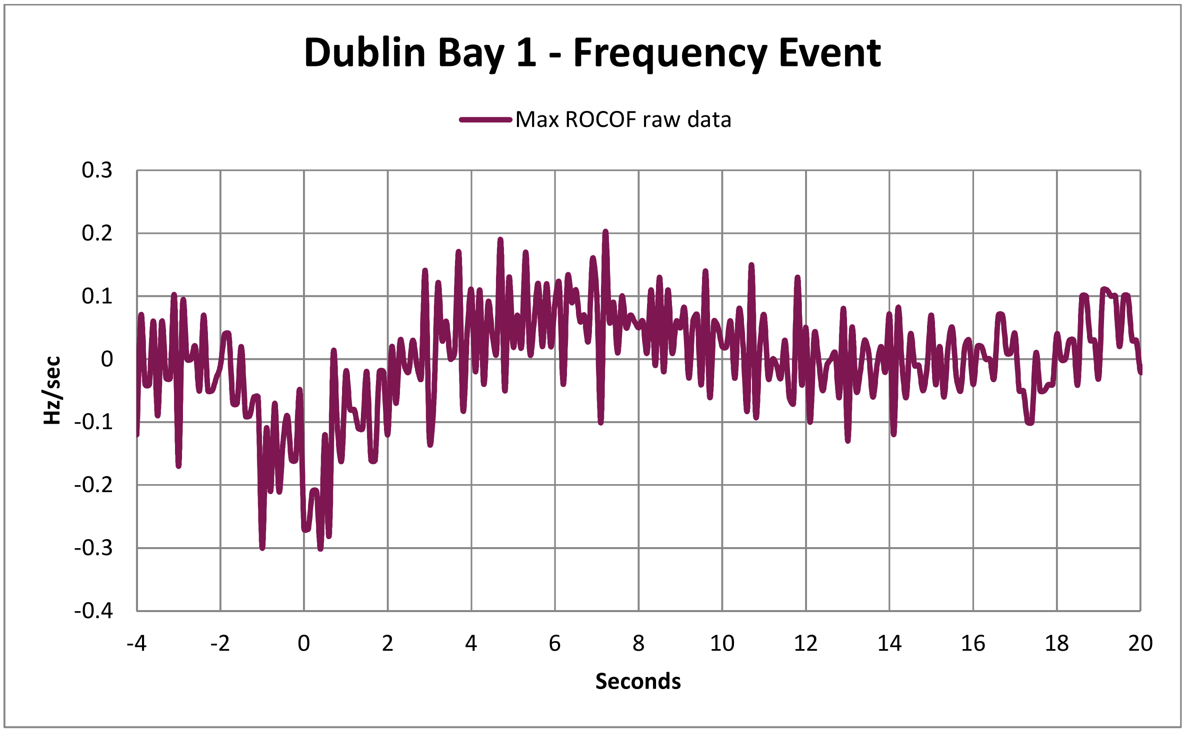


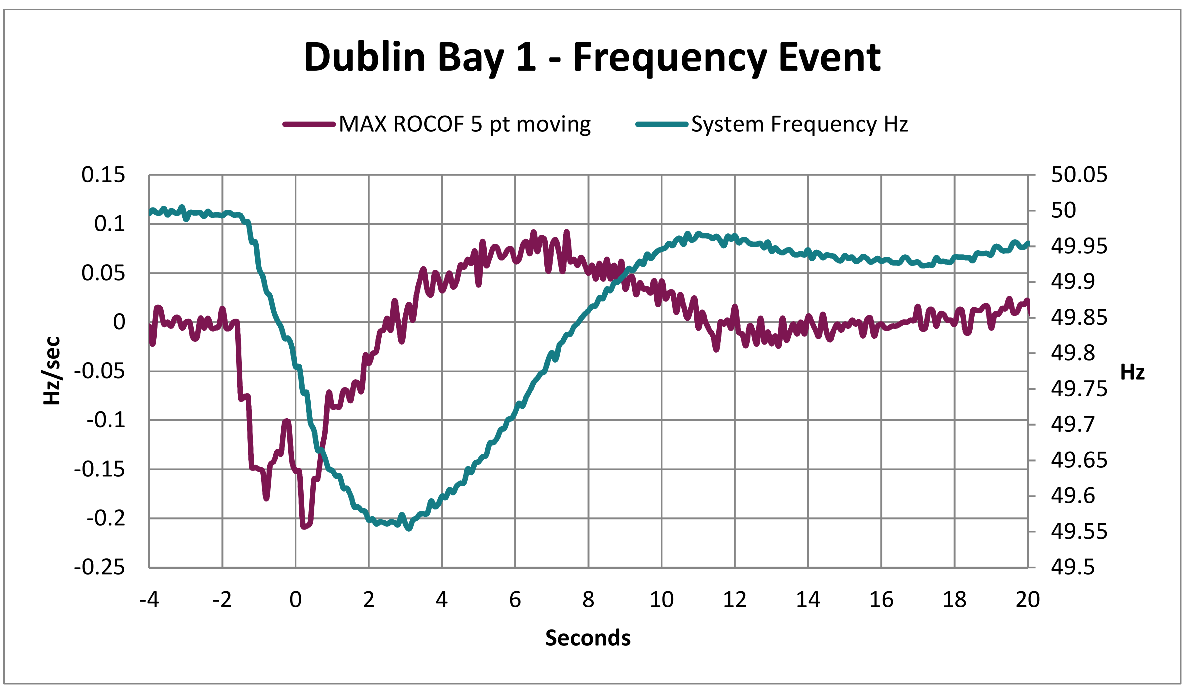


Dublin Bay – 22/01/2016






Dublin Bay 1 - Frequency Event
Max ROCOF raw data
Hz/sec
Seconds
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-4
-2
0
2
4
6
8
10
12
14
16
18
20


Dublin Bay 1 - Frequency Event
MAX ROCOF 5 pt moving
System Frequency Hz
Hz/sec
Hz
Seconds
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
50.05
50
49.95
49.9
49.85
49.8
49.75
49.7
49.65
49.6
49.55
49.5
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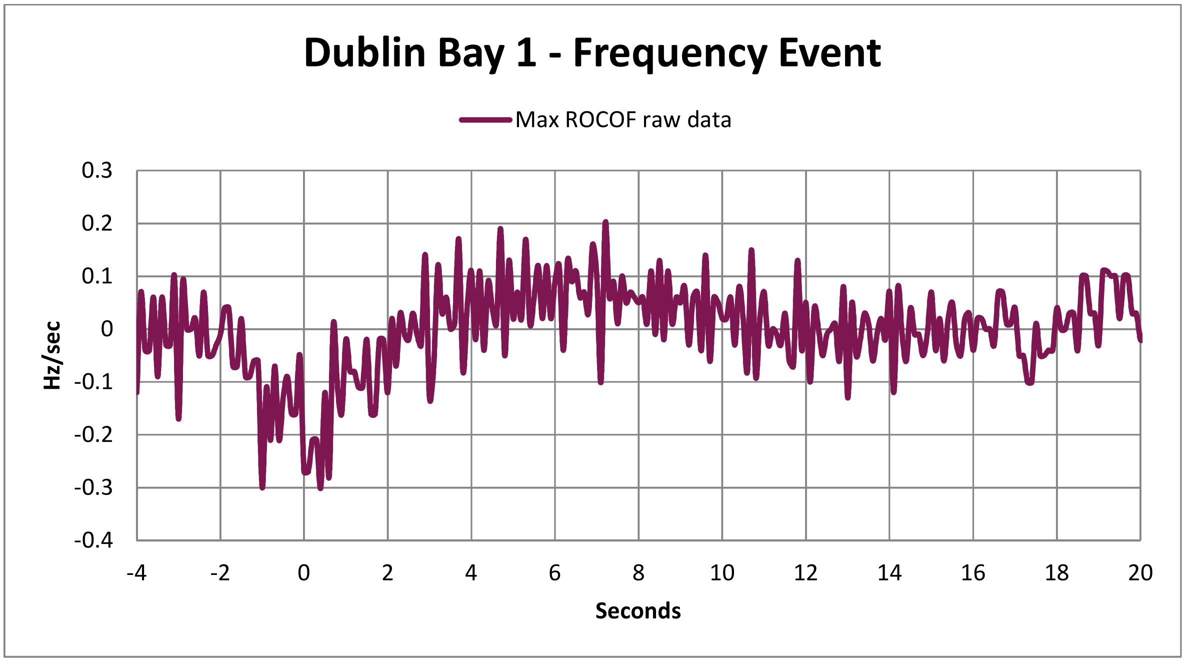
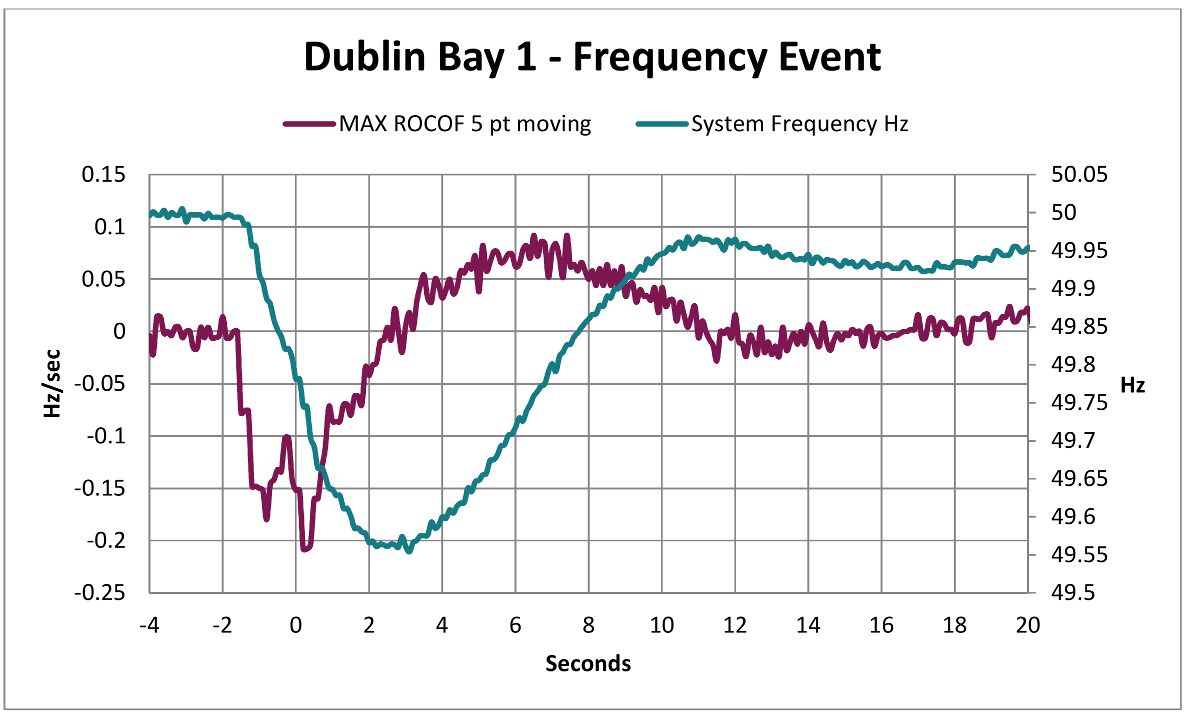
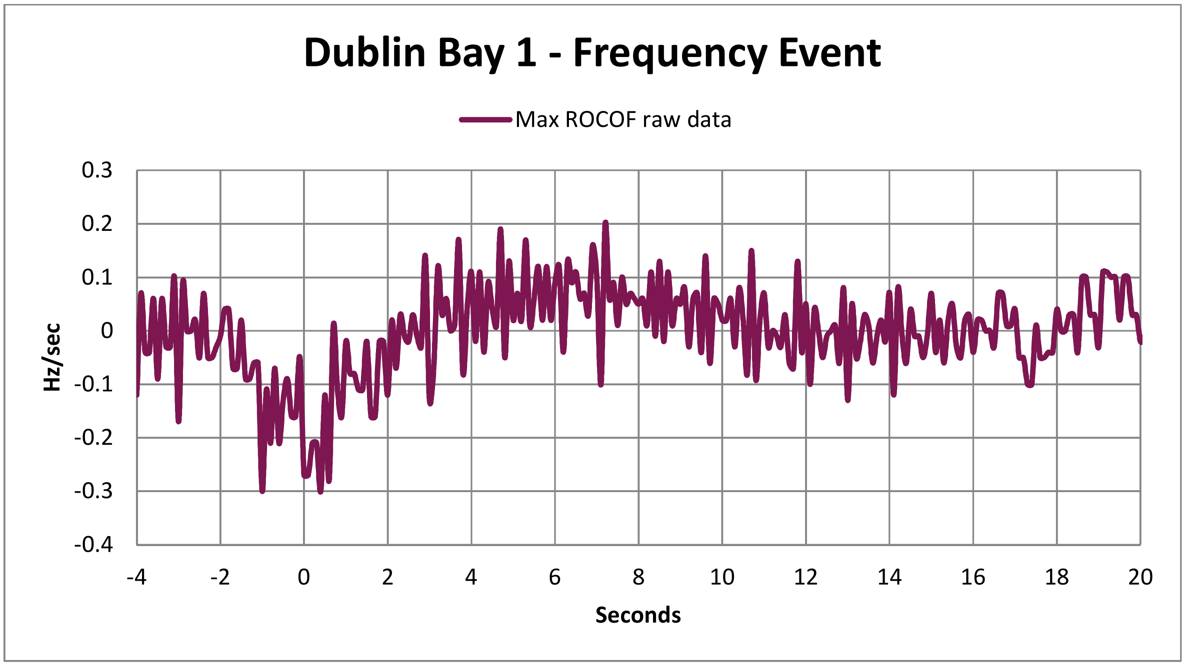
12
14
16
18
20


Dublin Bay 1 - Frequency Event
Max ROCOF raw data
Hz/sec
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-4
-2
0
2
4
6
8
10
12
14
16
18
20
Seconds


Dublin Bay 1 - Frequency Event
MAX ROCOF 5 pt moving
System Frequency Hz
Hz/sec
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
Hz
50.05
50
49.95
49.9
49.85
49.8
49.75
49.7
49.65
49.6
49.55
49.5
-4
-2
0
2
4
6
8
10
12
14
16
18
20
Seconds


Dublin Bay 1 - Frequency Event
Max ROCOF raw data
Hz/sec
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
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-4
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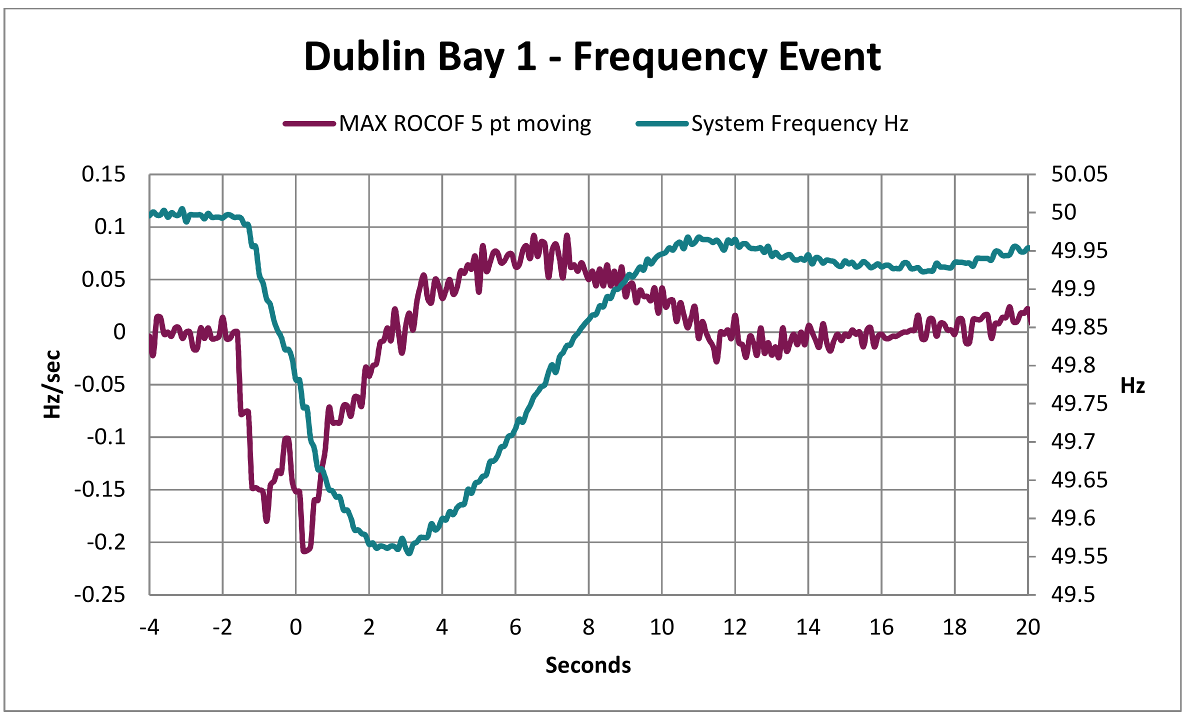
2
4
6
8
10
12
14
16
18
20
Seconds


Dublin Bay 1 - Frequency Event
MAX ROCOF 5 pt moving
System Frequency Hz
Hz/sec
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
50.05
50
49.95
49.9
49.85
49.8
49.75
49.7
49.65
49.6
49.55
49.5
Hz
-4
-2
0
2
4
6
8
10
12
14
16
18
20
Seconds

Appendix 3 All Island Fully Dispatchable Generation Plant

Company	Unit	Capacity (MW)	Fuel	365-day Rolling Availability %
Activation Energy	AEDSU - AE1	101	DSU	52.42
	AEDSU - AE2	9	DSU	67.74
	AEDSU - AE3	14	DSU	94.09
	AEDSU - AE4	12	DSU	100.00
AES	Ballylumford - B10	94	Gas / Distillate Oil	87.05
	Ballylumford - B21	249	Gas / Distillate Oil	87.44
	Ballylumford - B22	249	Gas / Distillate Oil	79.83
	Ballylumford - BGT1	58	Distillate	95.03
	Ballylumford - BGT2	58	Distillate	94.65
	Ballylumford - BPS4	147	Gas / Distillate Oil	69.29
	Ballylumford - BPS5	144	Gas / Distillate Oil	85.84
	Kilroot - KGT1	29	Distillate	83.96
	Kilroot - KGT2	29	Distillate	95.10
	Kilroot - KGT3	42	Distillate	89.93
	Kilroot - KGT4	42	Distillate	96.14
	Kilroot - KPS1	238	Coal / Heavy Fuel Oil	63.13
	Kilroot - KPS2	238	Coal / Heavy Fuel Oil	86.96
Aughinish Alumina Ltd	Seal Rock - SK3	85	Gas / Distillate Oil	89.93
	Seal Rock - SK4	85	Gas / Distillate Oil	90.39
Bord Gáis	Whitegate - WG1	444	Gas / Distillate Oil	96.16
Contour Global	ContourGAGU - CGA	12	Gas	99.05
Coolkeeragh ESB	Coolkeeragh - C30	408	Gas / Distillate Oil	92.06
	Coolkeeragh - CG8	53	Distillate	64.79
Dalkia Alternative Energy	DAE VPP - DP1	39	DSU	33.99
Endeco Technologies	EC1 - EC1	31	DSU	65.31
Edenderry Power Ltd	Edenderry - ED1	118	Peat	82.72
	Edenderry - ED3	58	Gas / Distillate Oil	99.36
	Edenderry - ED5	58	Gas / Distillate Oil	99.01
Electricity Exchange	Elect Exchng - EE1	20	DSU	65.45
	Electric Irl - EI1	20	DSU	81.43
Empower	EmpowerAGU - EMP	3	Distillate	100.00

Company	Unit	Capacity (MW)	Fuel	365-day Rolling Availability %
SSE Generation Ireland	Great Island - GI4	461	Gas / Distillate Oil	83.18
	Rhode - RP1	52	Distillate	93.74
	Rhode - RP2	52	Distillate	95.91
	Tarbert - TB1	54	Heavy Fuel Oil	59.40
	Tarbert - TB2	54	Heavy Fuel Oil	64.85
	Tarbert - TB3	241	Heavy Fuel Oil	94.15
	Tarbert - TB4	243	Heavy Fuel Oil	98.42
	Tawnaghmore - TP1	52	Distillate	97.70
	Tawnaghmore - TP3	52	Distillate	99.41
Energy Trading Ireland	Ener Trd Irl - ET1	11	DSU	79.01
ESBPG	Ardnacrusha - AA1	21	Hydro	70.59
	Ardnacrusha - AA2	22	Hydro	69.74
	Ardnacrusha - AA3	19	Hydro	69.23
	Ardnacrusha - AA4	24	Hydro	71.38
	Aghada - AD1	258	Gas / Distillate Oil	94.60
	Aghada - AD2	431	Gas / Distillate Oil	97.89
	Aghada - AT11	90	Gas / Distillate Oil	93.97
	Aghada - AT12	90	Gas / Distillate Oil	96.32
	Aghada - AT14	90	Gas / Distillate Oil	95.49
	Erne - ER1	10	Hydro	0.68
	Erne - ER2	10	Hydro	92.23
	Erne - ER3	22.5	Hydro	97.96
	Erne - ER4	22.5	Hydro	96.57
	Lee - LE1	15	Hydro	84.90
	Lee - LE2	4	Hydro	92.39
	Lee - LE3	8	Hydro	91.90
	Liffey - LI1	15	Hydro	35.93
	Liffey - LI2	15	Hydro	39.01
	Liffey - LI4	4	Hydro	39.27
	Liffey - LI5	4	Hydro	98.76
	Lough Ree - LR4	91	Peat	95.74
	Moneypoint - MP1	285	Coal / Heavy Fuel Oil	89.07
	Moneypoint - MP2	285	Coal / Heavy Fuel Oil	71.98
	Moneypoint - MP3	285	Coal / Heavy Fuel Oil	87.28
	Marina - MRC	95	Gas / Distillate Oil	86.89
	North Wall - NW5	104	Gas / Distillate Oil	92.75
	Poolbeg - PB14	150	Gas / Distillate Oil	97.53
	Poolbeg - PB15	150	Gas / Distillate Oil	98.58
	Poolbeg - PB16	163	Gas / Distillate Oil	93.93
	Turlough H - TH1	73	Hydro - Pumped Storage	96.20
	Turlough H - TH2	73	Hydro - Pumped Storage	96.42
	Turlough H - TH3	73	Hydro - Pumped Storage	96.99
	Turlough H - TH4	73	Hydro - Pumped Storage	97.33
	West Offaly - WO4	137	Peat	87.08

Company	Unit	Capacity (MW)	Fuel	365-day Rolling Availability %
ETI Ltd (NI)	ETR - ETR	12	DSU	37.95
Evermore	Lisahally - LPS	17.6	Biomass	74.39
Indaver	Indaver - IW1	17	Waste to Energy	90.26
iPower	iPower AGU - AGU	74	Distillate	97.49
PHG LTD	PHG - PH1	18	DSU	36.73
Powerhouse Generation	Powerhouse G - PG1	7	DSU	79.11
Synergen	Dublin Bay - DB1	405	Gas / Distillate Oil	96.21
Tynagh Energy Ltd	Tynagh - TYC	384	Gas / Distillate Oil	95.88
Viridian Energy Limited	Huntstown - HN2	400	Gas / Distillate Oil	94.38
	Huntstown - HNC	342	Gas / Distillate Oil	92.92
	Viridian DSU - VE1	6.9	DSU	38.83

Appendix 4 – EirGrid Maintenance Policy Terms

The following summarises the main terms and activities in the asset maintenance policy as operated by EirGrid[7]. 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: This includes condition monitoring, both on and offline, inspections and routine servicing. It is usually cyclical and can be planned in advance.

2. Corrective: Corrective maintenance may consist of repair, restoration or replacement of equipment before functional failure. Corrective maintenance requirements are identified through regular inspections. 3. Fault: Fault maintenance includes activities arising from unexpected equipment failure in service.

Stations

Preventive maintenance is carried out at routine intervals on all station assets regardless of age. The following summarises the primary routine preventative maintenance tasks on station equipment:

1. Operational tests: These involve, among other activities, opening and closing the breakers and disconnects locally and remotely, carrying out tripping checks on the breakers and checking of interlocking. These tests are designed to ensure that equipment will operate correctly when called upon to do so.

2. Ordinary services:

Every four years, or five years (depending on the voltage and location of the circuit in the system), more detailed inspection and measurements are taken. All measurements and test values are checked for conformity with standards or other norms established by best industry practice or experience. They are compared to those of previous measurements and tests. Any significant changes or trends are noted and satisfactory explanations sought.

3. Condition assessment

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

This non-invasive procedure combines an evaluation of the asset's operational, maintenance and fault histories with a detailed site inspection and site and laboratory tests. The condition assessment evaluates the asset's present condition and residual life and provides data for life management decisions i.e. required corrective maintenance, further monitoring, future operation (i.e. loading/ over-loading restriction, refurbishment, replacement, etc.). The EirGrid policy is to carry out condition assessments at eight-year or ten-year intervals depending on the asset type.

Overhead Lines

Outage related overhead lines maintenance works are condition/age based. To the greatest practical extent, inspections and condition assessments are carried out with the lines energised, and live working techniques are employed for some elements of remedial work. Planned maintenance of overhead lines implements requirements for preventative maintenance, corrective maintenance, and repairs, which are identified by inspections and condition assessments.

Cables

Inspections are carried out at monthly, quarterly and annual intervals for oil filled cables and at annual intervals for cross linked polyethylene (XLPE) cables. The principal cause of cable faults is third party damage or sheath faults.

Appendix 5 Formulae (EirGrid Transmission System)

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.

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