Needs Report

CP1021 North Dublin Corridor

November 2017

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2 Introduction

EirGrid's process on how to develop identified transmission network problems into viable technical solutions and further into construction and energisation is described in the document 'Have Your Say' published on EirGrid's website (www.eirgridgroup.com). On a high-level this process has six steps as shown below in figure 1. Each step has a distinct purpose with defined deliverables.

The Needs Report (this document) is a deliverable for Step 1. It will describe an identified transmission network problem. In this case the network problem is a shortage of capacity to transfer power along a corridor of 220 kV transmission lines in North Dublin. This corridor is between the Woodland 400 kV station to the north west of Dublin, the key load and generation centres at Finglas, Corduff, and Belcamp 220 kV stations, and load and generation in the city centre at Poolbeg and Shellybanks 220 kV stations.

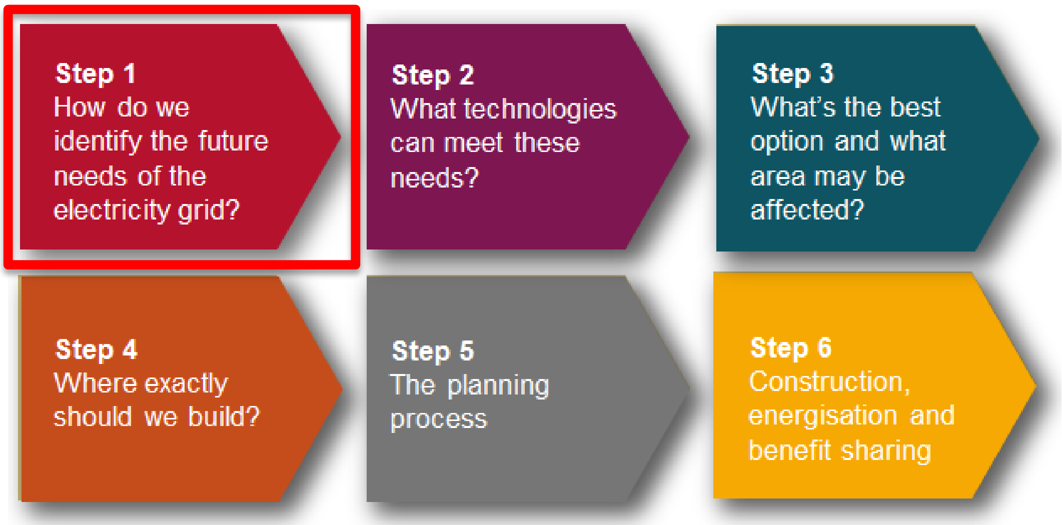

Figure 1 *High level project development process*

2.1 Our statutory role

EirGrid is the national electricity Transmission System Operator (TSO) for Ireland. Our role and responsibilities are set out in Statutory Instrument No. 445 of 2000 (as amended); in particular, Article 8(1) (a) gives EirGrid, the exclusive statutory function:

"To operate and ensure the maintenance of and, if necessary, develop a safe, secure, reliable, economical, and efficient electricity transmission system, and to explore and develop opportunities for interconnection of its system with other systems, in all cases with a view to ensuring that all reasonable demands for electricity are met and having due regard for the environment."

Furthermore, as TSO, we are statutorily obliged to offer terms and enter into agreements, where appropriate and in accordance with regulatory direction, with those using and seeking to use the transmission system. Upon acceptance of connection offers by prospective network generators and demand users, we must develop the electricity transmission network to ensure it is suitable for those connections.

3 Regulatory Targets and Policy

One of EirGrid’s roles is to plan the development of the electricity transmission grid to meet the future needs of society. To do this we consider how electricity may be used and generated years from now and what this means for the electricity grid of today.

The key to this process is considering the range of possible ways that energy usage may change in the future. This means that we will analyse different scenarios that would represent this. Using this approach will allow us to efficiently develop the grid taking account of the uncertainties associated with the future demand for electricity and the future location and technology used to generate electricity.

3.1 EirGrid scenarios

To help us account for the uncertainties of the future, EirGrid have published a document titled *Tomorrow’s Energy Scenarios 2017* to capture the range of possible future scenarios in energy production and usage. These scenarios were formed by EirGrid following a period of public consultation and with significant input from government departments and agencies, energy research groups, and industry representatives. Four future scenarios have been developed: Steady Evolution, Low Carbon Living, Slow Change and Consumer Action.

At the time of this need investigation the transition to Scenario Planning was not complete and the study cases required for analysis were not available. Bespoke study cases were created for this needs assessment.

When the input data for the Tomorrows Energy Scenarios became available the assumptions used in the study cases were compared with the scenarios. The assumptions were found to align with the three scenarios that have been developed for 2025. These are the Slow Change, Steady Evolution, and Low Carbon Living scenarios. Specific assumptions taken account of are:

- The demand levels in the cases, excluding data centre demand, were generally consistent with the demand levels presented in the Forecast Statement 2015-2024, which in turn takes information from the Generation Capacity Statement 2015-2024. These publications were the most up to date available at the time of the study. This assumption is very similar to the assumptions used in the Slow Change and Steady Evolution scenarios. However a number of new and existing customers in the Dublin region have requested new connections or increases in existing connection agreements.

- Connection of data centres has been accounted for in line with latest known information at this point in time. In total, just over 1200 MW of data centres have been assumed in the cases (see section 3.3 for more details). This figure is based on executed connection agreements and offered connection agreements. This assumption is in line with the assumed data centre demand figure used in the 2025 Low Carbon Living scenario, which is 1400 MVA.
- The connection of renewable generation to meet the Governance's renewable energy target of meeting 40% electricity demand from renewable generation by 2020 - covered by the Steady Evolution scenario.

In line with our statutory obligation the future scenarios are analysed to establish that the transmission system is in compliance with the Transmission System Security Planning Standards (TSSPS). If the system is in breach of any of these standards the issue must be addressed and a solution identified.

3.2 Study assumptions

The above mentioned assumptions were used to create the cases that were subsequently analysed. The year 2025 was chosen for analysis as it was deemed an appropriate point in time to assess the long term strategic needs of the system and to design reinforcement options to address those needs. Later years will be studied in Steps 2 and 3 solution option development, particularly when determining headroom created by the solutions. This year has been determined as the earliest stable point in the future to form a reliable development plan around. By this time it is expected that a number of network reinforcements will have been implemented, Gate 3 renewable generation will have been integrated into the system and a number of new loads will have been connected into the Dublin network.

Some of the reinforcements that have been assumed to be energised were:

- the series compensation of the existing 400 kV circuits,
- a 400 kV submarine cable across the Shannon Estuary between Moneypoint 400 kV station and Kilpaddoge 220 kV station,
- and reinforcement of the network between Dunstown and Woodland 400 kV stations.

A need to reinforce the network between Dunstown and Woodland 400 kV stations has been identified but the best performing solution option has not been selected at the time of this report. The solution option between Dunstown and Woodland assumed for the purposes of this study was the creation of a new 400 kV circuit between the stations. This new circuit is achieved by increasing the voltage of an existing 220 kV path between the stations to 400 kV using innovative tower reconstruction methods. The inclusion of this network solution will have little impact on the outcome of this study as the issues in the Kildare to Meath Reinforcement Project, and North Dublin are unrelated.

The existing Moyle Interconnector and East-West Interconnector (EWIC) were assumed available in 2025. Moyle and EWIC will be assumed to have 500 MW import/export capacity.

Two seasonal variations were studied to examine the effect of different load profiles and ratings: Winter Peak and Summer Peak. Winter and Summer Peak represent points in time when the system is most heavily loaded and therefore the time when there is most likely to be thermal issues on the system and low voltage risks. A minimum load case was not considered at this time because problems along the North Dublin Corridor are related to increases in demand. The minimum load is forecasted to grow due to the addition of substantial amounts of data centre demand which, unlike traditional demand, is time invariant. Therefore any problems associated with low load (such as the control of high voltages) are likely to improve. If new cables are planned as part of any solution option to high demand problems the need for minimum demand cases will be re-visited.

3.3 Demand Assumptions

Data centre load in Dublin is expected to grow substantially between now and 2025. At the time of this report some 338 MW of data centres are already connected in Dublin. Three phases of new data centre demand are assumed, based on requests for connection and offers for connection that have been accepted:

- Phase 1 – applicants that have accepted connection offers;
- Phase 2 – applicants with offers yet to be accepted;
- Phase 3 – additional possible future applicants (‘speculative’).

The volumes of new load and the expected connection points in each phase are shown in Table 1 below.

Project Name	Nearest Transmission Node	MIC (MW)
Phase 1		
Bancroft	Carrickmines County 110 kV	40
Jacobs	Inchicore 110 kV	70
Newbury	Belcamp 110 kV	27
Clonshaugh/Finglas	Belcamp 110 kV	40
Cloghran	Corduff 110 kV	49
Clonee	Corduff 110 kV	73
West Dublin	West Dublin 110 kV	108
Snugborough	Corduff 110 kV	22
Phase 1 Total		**429**
Phase 2		
Clonee	Corduff 110 kV	37
Cruiserath	Corduff 110 kV	267
Belcamp1	Belcamp 110 kV	56
Snugborough	Corduff 110 kV	40
Belcamp2	Belcamp 110 kV	46
Phase 2 Total		**446**
Phase 1 & 2 Total		**(875)**
Phase 3		
	Corduff 110 kV	135
	West Dublin 110 kV	135
	Belcamp 110 kV	135
Phase 3 Total		**405**

Table 1 *Data Centre Demand Assumed*

3.4 Generation Assumptions

The existing portfolio of large generation in Dublin was assumed to be available for these studies. The generators assumed are:

- Dublin Bay Unit 1, at Irishtown 220 kV station,
- Poolbeg Combined Cycle, at Shellybanks 220 kV station,
- Huntstown 1, at Finglas 220 kV station,
- Huntstown 2, at Corduff 220 kV station,
- North Wall Combined Cycle, at North Wall 220 kV station,
- Dublin Waste to Energy, at Poolbeg 220 kV station.

The generators that can have the greatest influence on power flows in North Dublin are Poolbeg Combined Cycle, Huntstown 1, and Huntstown 2. The availability and dispatch of these generators is a key input to this study.

Of the remaining generators, the following assumptions were made for this study:

- North Wall Combined Cycle was assumed to not run due to the running expense and age of the plant. It is assumed likely that this generator will be closed by the year of this analysis.

- Dublin Waste to Energy was assumed to always be running. This generator is relatively small and does not have the same influence on power flows in Dublin as the larger generators.

3.5 Study Cases

The study cases selected are outlined in Table 2 below.

Study Case		**Data Centre Demand Assumptions**	**Key Generation in Dublin**	**Inter connection**	**Network**	**Wind**
1a	Winter Peak	Phase 1 & 2	Dublin Bay (DB1, Huntstown 2 (HN2), Huntstown 1 (HNC), Poolbeg/Shellybanks (PBC)	EWIC Import Moyle Import	North South Interconnector In Regional Solution In Kildare – Meath Reinforcement In	All-Island 30% Winter Peak 20% Summer Peak
1b	Summer Peak					
2a	Winter Peak	Phase 1 & 2	3 large units in Dublin			
2b	Summer Peak					
3a	Winter Peak	Phase 1,2 & 3	DB1, HN2, PBC, HNC			
3b	Summer Peak					
4a	Winter Peak	Phase 1,2 & 3	3 large units in Dublin			
4b	Summer Peak					

Table 2 *Study Cases*

These study cases are designed to highlight issues associated with new large data centre loads emerging in Dublin (and North Dublin in particular) and identify resulting transmission constraints. To test the performance of the Woodland – Belcamp corridor generator dispatch patterns were set up to create power flows from west of Dublin towards the eastern side of the city. This was achieved with supply from Woodland via imports on the east-west interconnector (EWIC), low generation in north Dublin and increasing loads at Corduff, Finglas and Belcamp.

4 Statement of Need

There are two key drivers that highlight the need to develop the transmission system in North Dublin, shown in Figure 2, namely:

1. **Increased demand in North Dublin**. New data centre demand is concentrated around North Dublin. These data centres are located at, or near, the existing substations at Corduff, Finglas, and Belcamp. There are a limited number of circuits to supply these zones and constraints are likely as installed demand capacity increases.

2. **Low Generation in Dublin.** There are four generation stations in Dublin connected at Finglas, Corduff, Shellybanks, and Irishtown respectively. The generators at Finglas, Corduff, and Shellybanks can be used to supply the load in north Dublin and offset flows from Woodland towards Corduff. However, these generators are likely to be overtaken in the merit order by newer, more efficient, conventional generators and increasing levels of renewables. Renewable generation is generally built remote from Dublin and new power stations could be located outside Dublin. This means the power produced will have to be transported to get to where it is needed around Corduff, Finglas, and Belcamp.

These two factors drive the requirement for additional transmission network capacity in North Dublin diagnosed by non-compliance with the Transmission System Security Planning Standards (TSSPS).

The TSSPS contains a number of tests of the robustness of the transmission system. These are:

- N-1, the unplanned tripping of one item of transmission equipment at any time.
- N-G-1, the unplanned tripping of one item of transmission equipment at any time concurrent with a planned or unplanned outage of a generator.
- N-1-1, the unplanned tripping of one item of transmission equipment concurrent with a planned outage of one other item of transmission equipment during the maintenance outage season (between March and September).

Our analysis has shown that the N-G-1 test is breached. When one of the key generators in North Dublin is unavailable a subsequent unplanned loss of either of the existing two 220 kV circuits between Woodland, Corduff, and Finglas substations will overload the remaining parallel circuit. If the network is re-configured to re-route power away from these circuits then violations occur on the opposite end of the corridor on the Finglas – Poolbeg 220 kV and Finglas – Shellybanks 220 kV cable circuits.

Further reductions in available generation in Dublin, or increases in demand connections, are shown to make the overloads worse.

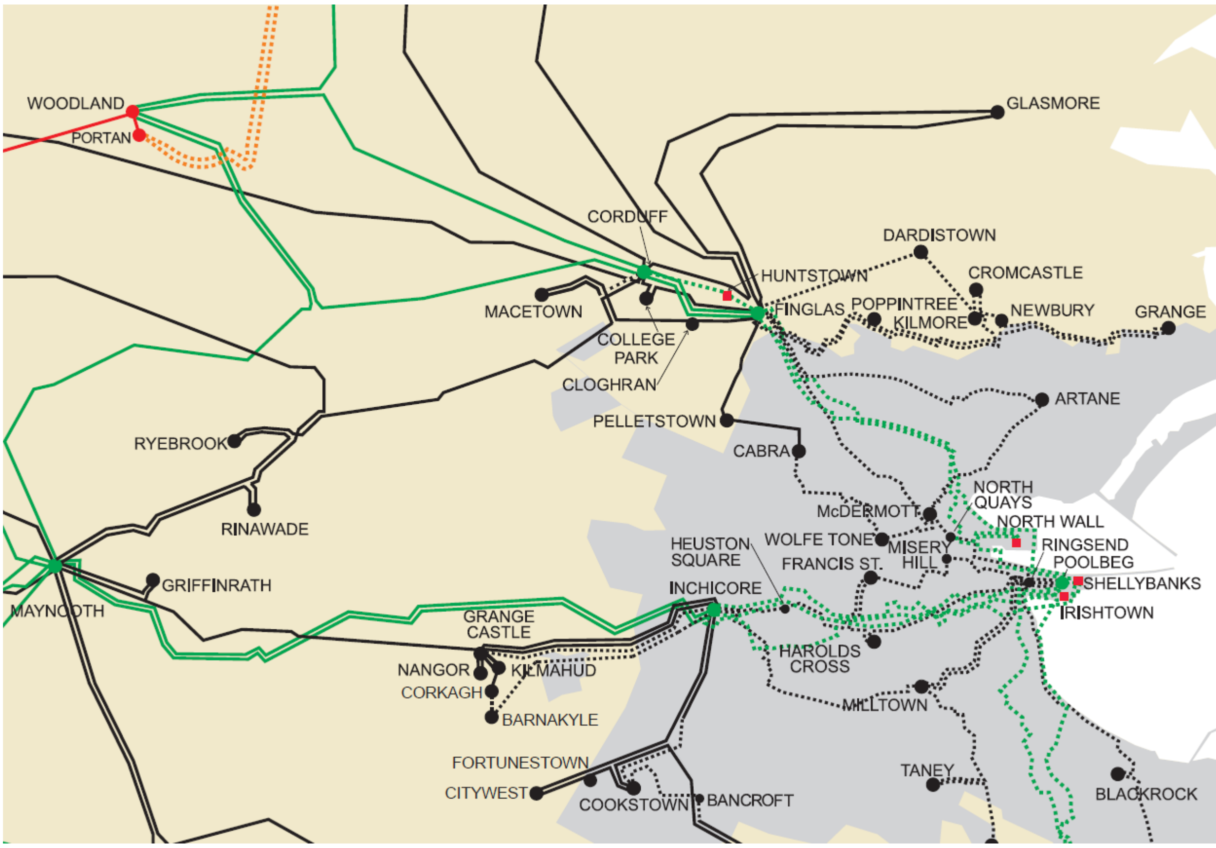

Figure 2 *Map of the North Dublin area showing the Transmission Network.*

5 Detailed Analysis

This chapter describes, in detail, the network problems which were identified for each of the four study cases.

Load flow results are shown for each study case in turn including problems identified from N-1, N-G-1, and N-1-1 tests.

The results of the Less Probable Contingency (LPC) assessments are shown where applicable. LPCs are where multiple items of transmission equipment are lost at the same time for the failure of a single item. For example, a double circuit tower failure removing two circuits from service simultaneously. These events are rare but are of interest where consequences are potentially severe.

The arrangement of the network in Dublin can be changed to help manage power flows and short circuit current levels. The normal arrangement is intended to provide the highest levels of security of supply but an alternative arrangement can be put in place following certain faults or in advance of planned outages.

5.1 Dublin network arrangement

The network in Dublin can be rearranged in response to changes in the pattern of dispatched generation to manage power flow and short circuit current levels.

Changing the network layout at Shellybanks 220 kV station is done in response to analysis carried out by Neartime and Realtime operations in support of the National Control Room.

The rearrangement can be put in place in response to an unplanned tripping on the network to ensure continued security of the network. The network can also be rearranged during planned outages to avoid system security concerns following a subsequent unplanned tripping of network equipment.

The normal and alternative arrangements are described below and the reasons why the different arrangements could be used are described.

5.1.1 Normal arrangement

The ‘normal’ running arrangement for Dublin with four large generator units dispatched is shown below. The network in Dublin is designed with a north-south split for power flow and short circuit current level management purposes. When four large generators are dispatched in Dublin short circuit current levels are a particular concern so this split is in place at those times.

The network split is made at the Poolbeg and Shellybanks 220 kV stations.

At Poolbeg 220 kV station the split is created using the inter-bus tie reactor to make either side of the split appear electrically far apart.

At Shellybanks 220 kV the substation is operated with a normally open point on the busbar. The three generation units that make up Poolbeg Combined Cycle generation are connected at Shellybanks. One of these units is usually connected to the north Dublin network and two to the south. This is shown in Figure 3.

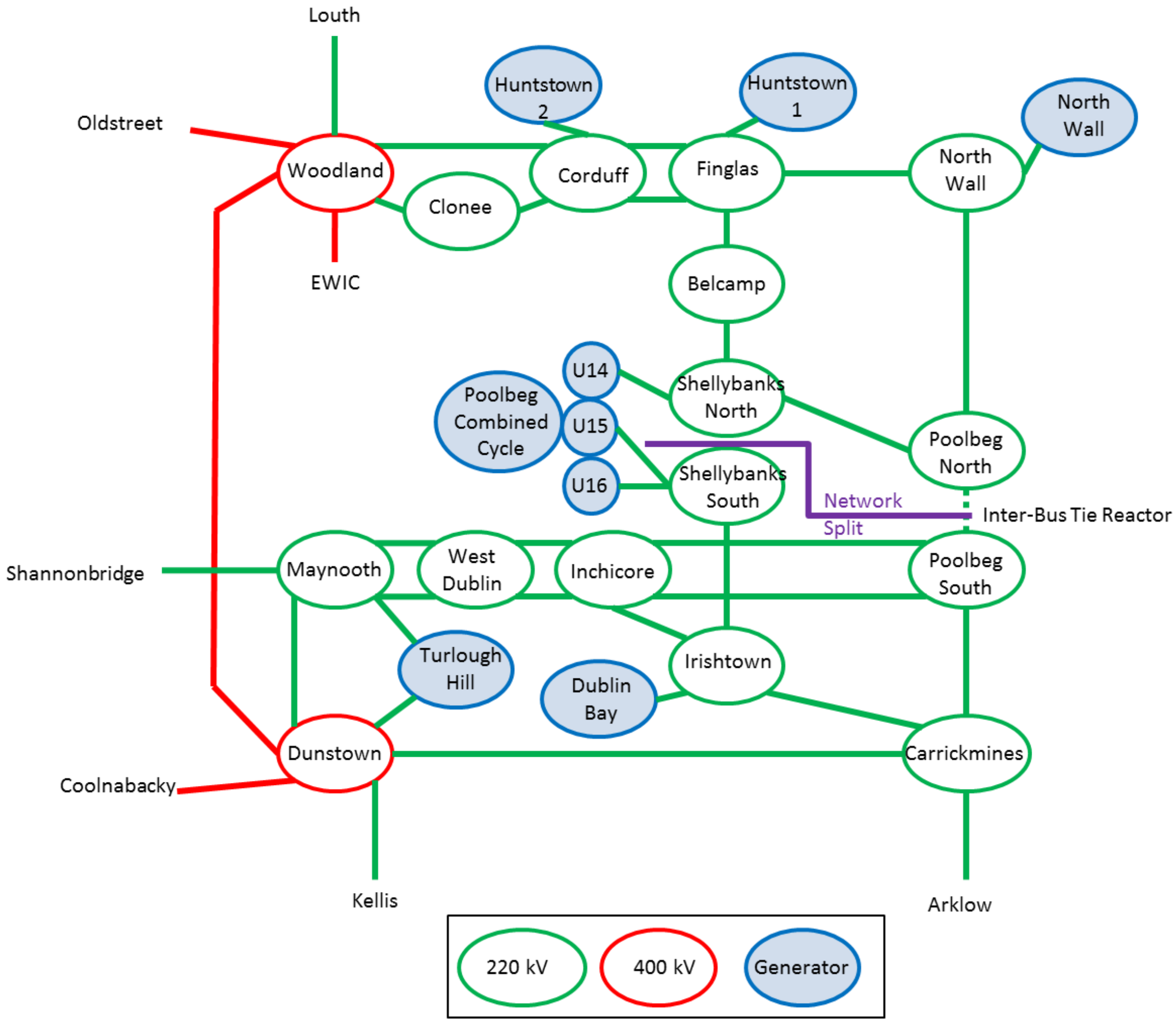

Figure 3 *Dublin Normal Running Arrangement*

5.1.2 Alternative arrangement

When one or more of the large generators in Dublin is not dispatched the network split at Shellybanks 220 kV station can be re-arranged, or closed.

When either of the Huntstown generators are unavailable power flows on the Corduff - Woodland and Corduff – Clonee – Woodland 220 kV circuits to the load at Corduff, Finglas, and Belcamp increase and can lead to overloads of the circuits. The Shellybanks 220 kV station split can be re-arranged to connect more Shellybanks generation to the north side of the Dublin network. This generation can then offset flows from Woodland to Corduff and achieve a better balance of power flow. All three units at

Shellybanks cannot be re-selected to the north side of the open-point when the units are at full output without overloading the cables north of Shellybanks. This leaves the option to rearrange Shellybanks to connect two of the PBC units to Belcamp and one unit to Poolbeg. This results in the three PBC units on the north side of the Dublin split but with reduced security of supply as the unplanned loss of one item of transmission equipment could lead to two of the PBC units being isolated from the network. This arrangement is shown below in Figure 4.

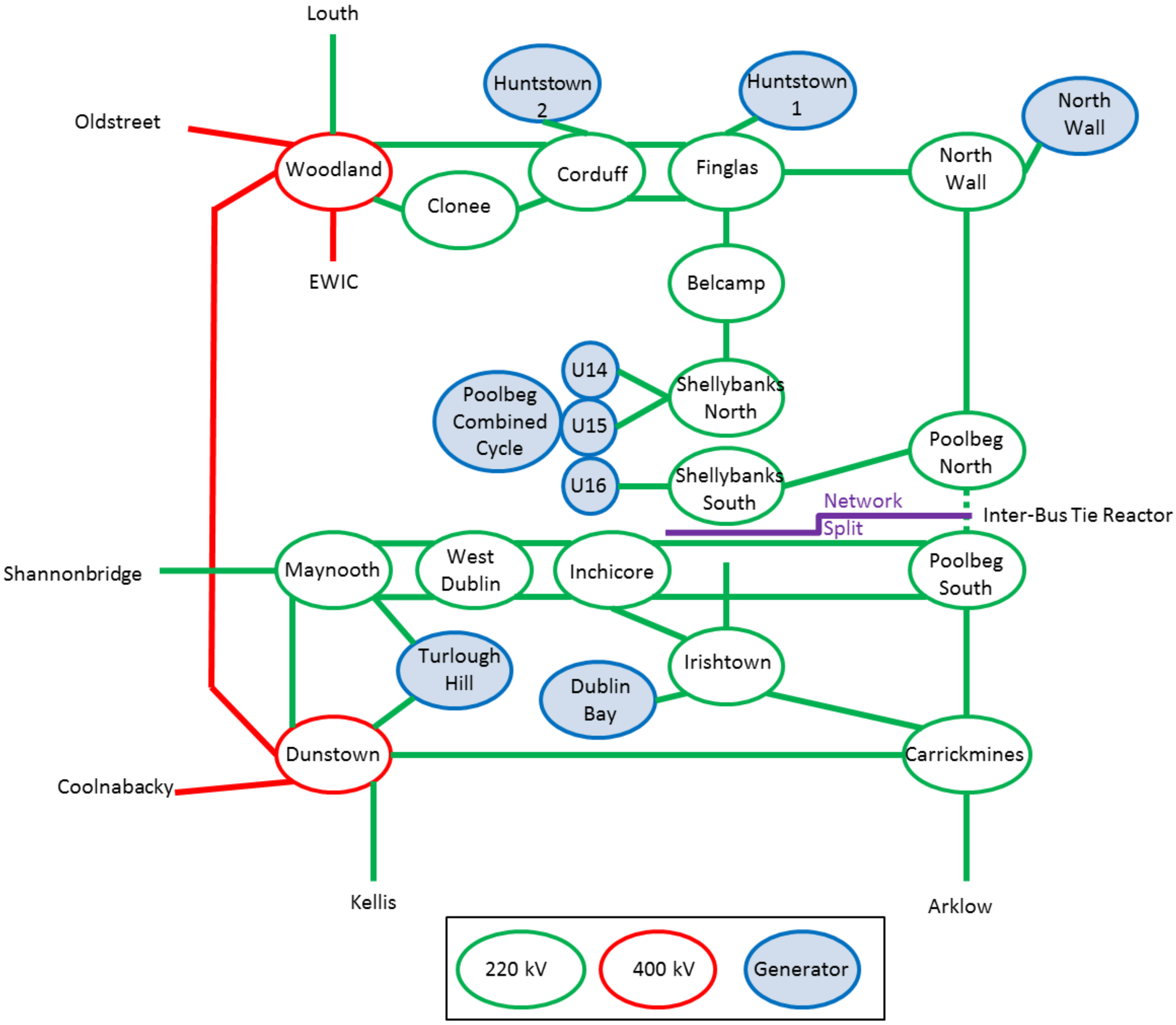

Figure 4 *Alternative Running Arrangement*

5.2 Case 1 – Base Case

5.2.1 Description of the case

This is the base case. It assumes no changes to the existing portfolio of generators in Dublin with 4 units, Dublin Bay 1, Huntstown 1, Huntstown 2, and Poolbeg Combined Cycle available for dispatch. This case is designed to identify network constraints associated with the connection of 875 MW of new data centre demand as offered.

Study Case		Data Centre Demand Assumptions	Generation Participating in Market in Dublin	Inter connection	Network	Wind
1a	Winter Peak	Phase 1 & 2	Dublin Bay (DB1), Huntstown 2 (HN2), Huntstown 1 (HNC), Poolbeg/Shellybanks (PBC)	EWIC Import Moyle Import	North South Interconnector In Regional Solution In Kildare – Meath Reinforcement In	All-Island 30% Winter Peak 20% Summer Peak
1b	Summer Peak					

Table 3 *Summary of inputs to Case 1*

5.2.2 Overview of problems

An overview of compliance with the TSSPS for this case is shown in Table 4 below.

Season	N-1	N-G-1	N-1-1
Winter Peak	✓	✓	Not Applicable
Summer Peak	✓	✗	✓

Table 4 *Case 1 Compliance with TSSPS*

Case 1b fails on N-G-1 at Summer Peak. With one generator outage in the north Dublin area the network cannot cope with the unplanned loss of one circuit. This is explained in the following sections.

5.2.3 TSSPS tests results

5.2.3.1 Normal network

Results are shown in Table 5 below for analysis of the Dublin network with the normal running arrangement (shown in section 5.1.1).

Season	Network Contingency		Overloaded Circuit			
			Circuit	Loading (%)	Loading (MVA)	Rating (MVA)
Winter Peak	N-1	Clonee – Woodland 1 220 kV cct	Corduff - Woodland 2 220 kV cct	**74%**	**395**	**534**
Summer Peak	N-1	Clonee – Woodland 1 220 kV cct	Corduff - Woodland 2 220 kV cct	**76%**	**330**	**434**
Winter Peak	N-G-1	'G' – HNC Clonee – Woodland 1 220 kV cct	Corduff - Woodland 2 220 kV cct	**98%**	**523**	**534**
Winter Peak	N-G-1	'G' – HN2 Clonee – Woodland 1 220 kV cct	Corduff - Woodland 2 220 kV cct	**102%**	**545**	**534**
Summer Peak	N-G-1	'G' – HNC Clonee – Woodland 1 220 kV cct	Corduff - Woodland 2 220 kV cct	**114%**	**495**	**434**
Summer Peak	N-G-1	'G' – HN2 Clonee – Woodland 1 220 kV cct	Corduff - Woodland 2 220 kV cct	**119%**	**516**	**434**

Table 5 *Results of TSSPS Tests for Case 1*

There are overloads for N-G-1.

There are no N-1 or N-1-1 problems.

The N-G-1 problems are for the unavailability of either HNC or HN2 and the subsequent unplanned loss of the Clonee – Woodland 220 kV line. This results in the unacceptable overload of the remaining Corduff - Woodland 220 kV line for summer peak. Overloads less than 110% are acceptable provided the overload can be removed within 30 minutes. Overloads on cable circuits are dependent on the design of the cable, and the pre-contingent loading, and are considered on a case-by-case basis.

5.2.3.2 Alternative network

To prepare for a planned generator outage (in this case, HN2 unavailable) the network can be rearranged to the configuration described in 5.1.2. The rearrangement was found not to be effective at removing the overloads.

5.3 Case 2 – Dublin generation unavailable

5.3.1 Description of the case

Of the four large generators in Dublin, three have a significant influence on power flows in North Dublin. These are the two Huntstown generators (HNC and HN2), and the Poolbeg combined cycle plant (PBC, consisting of three units). This case will focus on the impact of any one of these key generators being unavailable for any reason, resulting in three large units left available in the Dublin area.

This case is considered due to increasing penetration of renewables, new more efficient generators, changes to the energy market, and the advancing age of the generation in Dublin.

Generators in Dublin are also central to the need case for transmission reinforcement in North Dublin given their proximity to the new loads and ability to reduce the amount of network capacity required through offsetting flows along the North Dublin corridor. It is therefore vital to understand the networks ability to supply the contracted load changes should a generator unit become unavailable.

<table>
<tr><th colspan="2">Study Case</th><th>Data Centre Demand Assumptions</th><th>Generation Participating in Market in Dublin</th><th>Inter connection</th><th>Network</th><th>Wind</th></tr>
<tr><td>2a</td><td>Winter Peak</td><td rowspan="2">Phase 1 & 2</td><td rowspan="2">3 large units in Dublin</td><td rowspan="2">EWIC Import
Moyle Import</td><td rowspan="2">North South Interconnector In

Regional Solution In

Kildare – Meath Reinforcement In</td><td rowspan="2">All-Island

30% Winter Peak

20% Summer Peak</td></tr>
<tr><td>2b</td><td>Summer Peak</td></tr>
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Table 6 *Summary of inputs to Case 2*

5.3.2 Overview of problems

An overview of compliance with the TSSPS for this case is shown in Table 7 below.

Season	N-1	N-G-1	N-1-1
Winter Peak	✓	✗	Not Applicable
Summer Peak	✗	✗	✗

Table 7 *Case 2 Compliance with TSSPS*

Case 2 fails on N-1, N-G-1, and N-1-1 at Summer Peak, and for N-G-1 at Winter Peak. A case with three generators in North Dublin cannot be made compliant for the concurrent loss of one generator and one item of transmission equipment. It follows that further outages of either lines or a generator make the situation worse. This is explained in the following sections.

5.3.3 TSSPS tests results

Each of the three generators, PBC, HNC and HN1, were removed in turn and studies repeated for N-1, N-G-1, and N-1-1. Results are shown in the following sections.

5.3.3.1 HN2 Unavailable

Huntstown 2 (HN2) is connected at Corduff 220 kV station. With this generator unavailable the network is re-arranged to the alternative layout shown in 5.1.2. This network rearrangement was used in this study in preparation for a contingency to help manage unacceptable overloads of the Corduff – Woodland and Clonee – Corduff 220 kV circuits identified with the network in the normal layout.

Season	**Network Contingency**		**Overloaded Circuit**			
			Circuit	Loading (%)	Loading (MVA)	Rating (MVA)
Winter Peak	N-1	Clonee – Woodland 1 220 kV cct	Corduff – Woodland 2 220 kV cct	**84%**	**448**	**534**
Winter Peak	N-1	Corduff - Woodland 2 220 kV cct	Clonee – Woodland 1 220 kV cct	**86%**	**460**	**534**
Summer Peak	N-1	Clonee – Woodland 1 220 kV cct	Corduff - Woodland 2 220 kV cct	**100%**	**434**	**434**
Summer Peak	N-1	Corduff - Woodland 2 220 kV cct	Clonee – Woodland 1 220 kV cct	**103%**	**447**	**434**
Winter Peak	N-G-1	'G' – HNC Corduff - Woodland 2 220 kV cct	Clonee – Woodland 1 220 kV cct	**113%**	**603**	**534**
Summer Peak	N-G-1	'G' – HNC Clonee – Woodland 1 220 kV cct	Corduff - Woodland 2 220 kV cct	**144%**	**625**	**434**
Summer Peak	N-1-1	Corduff - Woodland 2 220V cct & Clonee – Woodland 1 220 kV cct	North Wall – Poolbeg 220 kV cct Finglas – North Wall 220 kV cct	**130%** **133%**	**429** **439**	**330** **330**

Table 8 *Results of TSSPS Tests for Case 2 – HN2 unavailable*

There are overloads for N-1, N-G-1, and N-1-1.

N-1 problems are for the loss of either Clonee – Woodland 220 kV line or Corduff – Woodland 220 kV line. This results in the overload of the remaining 220 kV line between Corduff and Woodland for summer peak. These overloads can be reduced post-fault by increasing the output on HNC and PBC to maximum and using up the margin left available for reserve.

Though increasing remaining generators to maximum is sufficient for N-1 there are more severe problems for N-G-1 and N-1-1 where this will not be enough. For a planned outage of HNC (on top of the unavailability of HN2) the overload for the loss of the Clonee – Woodland 220 kV line or Corduff – Woodland 220 kV line is made worse

(144% in Summer Peak). There is then not enough network capacity to feed the load in North Dublin even if the remaining generators are set to maximum.

For an N-1-1 involving the loss of Clonee – Woodland 220 kV line and Corduff - Woodland 220 kV line there are overloads on the North Wall – Poolbeg and Finglas – North Wall 220 kV cables.

5.3.3.2 HNC Unavailable

Huntstown 1 (HNC) is connected at Finglas 220 kV station. With this generator unavailable the network is re-arranged to the alternative layout shown in 5.1.2. This network rearrangement was used in this study in preparation for a contingency to help manage unacceptable overloads of the Corduff – Woodland and Clonee – Corduff 220 kV circuits identified with the network in the normal layout.

Season	**Network Contingency**		**Overloaded Circuit**			
			Circuit	Loading (%)	Loading (MVA)	Rating (MVA)
Winter Peak	N-1	Clonee – Woodland 1 220 kV cct	Corduff - Woodland 2 220 kV cct	**80%**	**427**	**534**
Winter Peak	N-1	Corduff - Woodland 2 220 kV cct	Clonee – Woodland 1 220 kV cct	**82%**	**438**	**534**
Summer Peak	N-1	Clonee – Woodland 1 220 kV cct	Corduff - Woodland 2 220 kV cct	**95%**	**412**	**434**
Summer Peak	N-1	Corduff - Woodland 2 220 kV cct	Clonee – Woodland 1 220 kV cct	**97%**	**421**	**434**
Winter Peak	N-G-1	'G' – HN2 Corduff - Woodland 2 220 kV cct	Clonee – Woodland 1 220 kV cct	**113%**	**603**	**534**
Summer Peak	N-G-1	'G' – HN2 Clonee – Woodland 1 220 kV cct	Corduff - Woodland 2 220 kV cct	**144%**	**625**	**434**
Summer Peak	N-G-1	'G' – PBC Corduff - Finglas 1 220_kV cct	Corduff - Finglas 2 220 kV cct	**105%**	**456**	**434**
Summer Peak	N-1-1	Corduff - Woodland 2 220 kV cct & Clonee – Woodland 1 220 kV cct	North Wall – Poolbeg 220 kV cct Finglas – North Wall 220 kV cct	**140%** **145%**	**462** **479**	**330** **330**

Table 9 *Results of TSSPS Tests for Case 2 – HNC unavailable*

The loss of either Clonee – Woodland 220 kV line or Corduff - Woodland 220 kV line (with HNC and HN2 out) results in the overload of the remaining Corduff - Woodland circuit for summer peak. These overloads cannot be reduced post-fault by increasing the output on PBC to maximum and there is not enough network capacity to feed the load in North Dublin.

The Corduff – Finglas 220 kV lines are also affected in this case for an N-G-1 test. The loss of PBC at Shellybanks 220 kV station when HNC at Finglas 220 kV station is unavailable leads to an N-1 overload on the Corduff – Finglas 220 kV lines.

For an N-1-1 involving the loss of Clonee – Woodland and Corduff - Woodland 220 kV lines there are overloads on the North Wall – Poolbeg and Finglas – North Wall 220 kV cables.

5.3.3.3 PBC Unavailable

With all units at PBC, connected at Shellybanks 220 kV station, unavailable there is no need to re-arrange the network and the normal layout described in 5.1.1 is used.

Season	Network Contingency		Overloaded Circuit			
			Circuit	Loading (%)	Loading (MVA)	Rating (MVA)
Winter Peak	N-1	Clonee – Woodland 1 220 kV cct	Corduff - Woodland 2 220 kV cct	**87%**	**465**	**534**
Winter Peak	N-1	Corduff - Woodland 2 220 kV cct	Clonee – Woodland 1 220 kV cct	**88%**	**470**	**534**
Summer Peak	N-1	Clonee – Woodland 1 220 kV cct	Corduff - Woodland 2 220 kV cct	**92%**	**399**	**434**
Summer Peak	N-1	Corduff - Woodland 2 220 kV cct	Clonee – Woodland 1 220 kV cct	**95%**	**412**	**434**
Winter Peak	N-G-1	'G' – HN2 Corduff - Woodland 2 220 kV cct	Clonee – Woodland 1 220 kV cct	**116%**	**619**	**534**
Summer Peak	N-G-1	'G' – HN2 Clonee – Woodland 1 220 kV cct	Corduff - Woodland 2 220 kV cct	**135%**	**586**	**434**
Summer Peak	N-1-1	Poolbeg 220_kV Reactor& Corduff - Woodland 2 220 kV cct	Clonee – Woodland 1 220 kV cct	**108%**	**356**	**330**

Table 10 *Results of TSSPS Tests for Case 2 – PBC unavailable*

There are no N-1 problems.

There are unacceptable overloads for N-G-1.

N-G-1 problems are for the loss of either Clonee – Woodland or Corduff - Woodland 220 kV lines (with HN2 out) which results in the overload of the remaining Corduff - Woodland 220 kV circuit. These overloads cannot be reduced post-fault by increasing the output on the single remaining generator in North Dublin (HNC) to maximum and there is not enough network capacity to feed the load in North Dublin.

An N-1-1 involving the loss of the Poolbeg 220 kV Inter-Bus Tie Reactor and Corduff – Woodland 220 kV line leads to overloads on the remaining Clonee – Woodland 220 kV line (108%).

5.3.3.4 Less Probable Contingency (LPC) Assessments

As available generation in the Dublin area is further reduced the issues described so far in section 5.3 worsen. In addition, the case begins to fail the Less Probable Contingency (LPC) test. LPC events are where multiple items of transmission equipment are lost at the same time for the failure of a single item, for example both circuits carried on the same double circuit tower.

The TSSPS does not permit any actions, before or after the event, to mitigate the effects of a LPC. The network must be designed to be robust enough to cope with these events.

5.3.3.4.1 Woodland – Corduff Double Circuit LPC

The Clonee – Corduff 220 kV and Woodland – Corduff 220 kV lines are hung on double-circuit towers for the last 2km towards Corduff 220 kV station. The failure of one of these towers can lead to the simultaneous loss of both Clonee – Corduff 220 kV and Woodland

– Corduff 220 kV lines. This can have catastrophic effects for certain load and generation combinations in Dublin.
In Summer Peak 2025, for example, when both Huntstown generators are not dispatched, or unavailable, the double-circuit loss of Clonee – Corduff 220 kV and Woodland – Corduff 220 kV lines can lead to cascading overloads and voltage collapse in the Dublin area.

5.3.3.4.2 Corduff – Finglas Double Circuit LPC

Corduff – Finglas 220 kV ‘1’ and ‘2’ circuits are hung on double-circuit towers for the majority of their 4km length. The failure of one of these towers can lead to the loss of both lines when the Shellybanks 220 kV network split is in place.
For Summer Peak 2025, with a north-south split at Shellybanks, if both HNC and PBC are unavailable then the double-circuit loss of Corduff – Finglas 220 kV leads to voltage collapse.

5.4 Case 3 – Additional speculative Dublin load

5.4.1 Description of the case

Case 3 has additional load in Dublin compared to the base case. An extra 150 MW was added at each of Corduff, Belcamp, and West Dublin 220 kV stations on top of that already issued with connection offers. These are considered likely locations for connections of further data centre loads. Loads were modelled at 0.95 p.f. leading (i.e. consuming reactive power). Case 3 assumes no changes to the existing portfolio of generators in Dublin and all four generators are available for dispatch. The purpose of this case is to identify network constraints should the connection of new data centre demand be increased further in the medium to long-term.

<table>
<tr><th colspan="2">Study Case</th><th>Data Centre Demand Assumptions</th><th>Generation Participating in Market in Dublin</th><th>Inter connection</th><th>Network</th><th>Wind</th></tr>
<tr><td>3a</td><td>Winter Peak</td><td rowspan="2">Phase 1,2 & 3</td><td rowspan="2">DB1, HN2, PBC, HNC</td><td rowspan="2">EWIC Import
Moyle Import</td><td rowspan="2">North South Interconnector In

Regional Solution In

Kildare – Meath Reinforcement In</td><td rowspan="2">All-Island

30% Winter Peak

20% Summer Peak</td></tr>
<tr><td>3b</td><td>Summer Peak</td></tr>
</table>

Table 11 *Summary of inputs to Case 3*

5.4.2 Overview of problems

An overview of compliance with the TSSPS for this case is shown in Table 12 below.

Season	N-1	N-G-1	N-1-1
Winter Peak	✓	✗	Not Applicable
Summer Peak	✗	✗	✗

Table 12 *Case 3 Compliance with TSSPS*

Case 3 fails on N-1, N-G-1, and N-1-1 at Summer Peak, and on N-G-1 at Winter Peak. With additional load in Dublin the network cannot be made N-1 compliant at Summer Peak. It follows that further outages of either lines of a generator make the situation worse. This is explained in the following sections.

5.4.3 *TSSPS tests results*

5.4.3.1 Normal network

Results are shown in Table 13 below for analysis of the Dublin network with the normal running arrangement (shown in section 5.1.1).

Season	Network Contingency		Overloaded Circuit			
			Circuit	Loading (%)	Loading (MVA)	Rating (MVA)
Winter Peak	N-1	Clonee – Woodland 1 220 kV cct	Corduff - Woodland 2 220 kV cct	**106%**	**566**	**534**
Winter Peak	N-1	Corduff - Woodland 2 220 kV cct	Clonee – Woodland 1 220 kV cct	**108%**	**577**	**534**
Summer Peak	N-1	Clonee – Woodland 1 220 kV cct	Corduff - Woodland 2 220 kV cct	**118%**	**512**	**434**
Summer Peak	N-1	Corduff - Woodland 2 220 kV cct	Clonee – Woodland 1 220 kV cct	**120%**	**521**	**434**
Winter Peak	N-G-1*	'G' – HN2 Corduff - Woodland 2 220 kV cct	Clonee – Woodland 1 220 kV cct	**135%**	**721**	**534**
Summer Peak	N-G-1*	'G' – HN2 Corduff - Woodland 2 220 kV cct	Clonee – Woodland 1 220 kV cct	**165%**	**716**	**434**
Summer Peak	N-1-1*	Corduff - Woodland 2 220 kV cct & Poolbeg 220_kV Reactor	Clonee – Woodland 1 220 kV cct	**145%**	**478**	**330**
	***No Network Switching (see section 5.4.3.2 instead)**					

Table 13 *Results of TSSPS Tests for Case 3*

There are overloads for N-1, N-G-1, & N-1-1.

N-1 problems are for the loss of either Clonee – Woodland or Woodland – Corduff 220 kV lines. This results in unacceptable overloads of the remaining Corduff - Woodland 220 kV line for summer peak. For winter peak, these overloads are below 110% and can be reduced post-fault by increasing the output on the remaining generators in North Dublin.

There are more severe problems for N-G-1 and N-1-1. For a planned outage of HN2 the overload for the loss of Clonee – Woodland or Corduff - Woodland 220 kV line is made worse (165% in Summer Peak). There is now not enough network capacity to feed the load in North Dublin even if the output of the remaining generators is set to maximum. For an N-1-1 involving the loss of Corduff - Woodland 220 kV line and the Poolbeg 220 kV Inter-Bus Tie Reactor there are unacceptable overloads on the Clonee – Woodland 220 kV line.

5.4.3.2 Alternative network

To prepare for a planned generator or line outage the network can be rearranged to that shown in 5.1.2. The rearrangement was found not to be effective at removing the overloads.

5.5 Case 4 – Dublin generation unavailable & additional speculative load

5.5.1 Description of the case

Case 4 is the most onerous case and combines the sensitivities examined on a reduced generation portfolio in North Dublin (Case 2) and increased data centre load (Case 3). One generator in Dublin from the existing portfolio is assumed unavailable and an extra 150 MW of load is added at each of Corduff, Belcamp and West Dublin on top of those demand already issued with connection offers. The purpose of this case is to identify network constraints and remaining margins should the connection of new data centre demand be increased in the medium to long-term when combined with a reduced portfolio of generation in Dublin.

Study Case		**Data Centre Demand Assumptions**	**Generation Participating in Market in Dublin**	**Inter connection**	**Network**	**Wind**
4a	Winter Peak	Phase 1,2 & 3	3 large units in Dublin	EWIC Import Moyle Import	North South Interconnector In Regional Solution In Kildare – Meath Reinforcement In	All-Island 30% Winter Peak 20% Summer Peak
4b	Summer Peak					

Table 14 *Summary of inputs to Case 4*

5.5.2 Overview of problems

An overview of compliance with the TSSPS for this case is shown in Table 15 below.

Season	**N-1**	**N-G-1**	**N-1-1**
Winter Peak	✗	✗	Not Applicable
Summer Peak	✗	✗	✗

Table 15 *Case 4 Compliance with TSSPS*

Case 4 fails on N-1, N-G-1, and N-1-1. A case with three generators in North Dublin cannot be made compliant for the concurrent loss of one generator and one item of transmission equipment. It follows that further outages of either lines of a generator make the situation worse. This is explained in the following sections.

5.5.3 *TSSPS tests results*

The extra load was added before each of the three key generators in North Dublin were removed in turn and studies repeated for N-1, N-G-1, and N-1-1. Results are shown in the following sections.

5.5.3.1 HN2 Unavailable

Huntstown 2 (HN2) is connected at Corduff 220 kV station. With this generator unavailable the network is re-arranged to the alternative layout shown in 5.1.2. This network rearrangement was used in this study in preparation of a contingency to help manage unacceptable overloads of the Corduff – Woodland 220 kV line identified with the network in the normal layout.

Season	Network Contingency		Overloaded Circuit			
			Circuit	Loading (%)	Loading (MVA)	Rating (MVA)
Winter Peak	N-1	Clonee – Woodland 1 220 kV cct	Corduff - Woodland 2 220 kV cct	**115%**	**614**	**534**
Winter Peak	N-1	Corduff - Woodland 2 220 kV cct	Clonee – Woodland 1 220 kV cct	**122%**	**651**	**534**
Summer Peak	N-1	Clonee – Woodland 1 220 kV cct	Corduff - Woodland 2 220 kV cct	**145%**	**629**	**434**
Summer Peak	N-1	Corduff - Woodland 2 220 kV cct	Clonee – Woodland 1 220 kV cct	**147%**	**638**	**434**
Winter Peak	N-G-1	'G' – HNC Corduff - Woodland 2 220 kV cct	Clonee – Woodland 1 220 kV cct	**150%**	**801**	**534**
Summer Peak	N-G-1	'G' – HNC Corduff - Woodland 2 220 kV cct	Clonee – Woodland 1 220 kV cct	**190%**	**825**	**434**
Summer Peak	N-1-1	Corduff - Woodland 2 220 kV cct & Clonee – Woodland 1 220 kV cct	North Wall – Poolbeg 220 kV cct	**115%**	**380**	**330**

Table 16 *Results of TSSPS Tests for Case 4 – HN2 unavailable*

There are overloads for N-1, N-G-1, and N-1-1.

N-1 problems are observed for the loss of either Clonee – Woodland or Corduff - Woodland 220 kV lines. This results in unacceptable overloads on the remaining Corduff - Woodland 220 kV line for summer peak and winter peak. These overloads cannot be reduced below 100% by increasing the output on HNC and PBC to maximum and using up the margin left available for reserve.

For a planned outage of HNC (on top of the unavailability of HN2) the overload for the loss of Clonee – Woodland or Corduff - Woodland 220 kV line is made worse (190% in Summer Peak). There is now not enough network capacity to feed the load in North Dublin even if the output of the remaining generator is set to maximum.

For an N-1-1 involving the loss of Clonee – Woodland and Corduff - Woodland 220 kV lines there are overloads on the Poolbeg – North Wall – Finglas cables. Only two lines are left to feed the load in North Dublin (North Wall – Poolbeg and Belcamp - Shellybanks 220 kV cables) along with the two remaining generators (HNC and PBC). This is not enough to feed the expanded load in North Dublin.

5.5.3.2 HNC Unavailable

Huntstown 1 (HNC) is connected at Finglas 220 kV station. With this generator unavailable the network is re-arranged to the alternative layout shown in 5.1.2. This network rearrangement was used in this study in preparation of a contingency to help manage unacceptable overloads of the Clonee – Woodland 220 kV line identified with the network in the normal layout.

Season	Network Contingency		Overloaded Circuit			
			Circuit	Loading (%)	Loading (MVA)	Rating (MVA)
Winter Peak	N-1	Clonee – Woodland 1 220 kV cct	Corduff - Woodland 2 220 kV cct	**105%**	**560**	**534**
Winter Peak	N-1	Corduff - Woodland 2 220 kV cct	Clonee – Woodland 1 220 kV cct	**108%**	**577**	**534**
Summer Peak	N-1	Clonee – Woodland 1 220 kV cct	Corduff - Woodland 2 220 kV cct	**140%**	**608**	**434**
Summer Peak	N-1	Corduff - Woodland 2 220 kV cct	Clonee – Woodland 1 220 kV cct	**142%**	**616**	**434**
Winter Peak	N-G-1	‘G’ – HN2 Corduff - Woodland 2 220 kV cct	Clonee – Woodland 1 220 kV cct	**150%**	**801**	**534**
Summer Peak	N-G-1	‘G’ – HN2 Clonee – Woodland 1 220 kV cct	Corduff - Woodland 2 220 kV cct	**190%**	**824**	**434**
Summer Peak	N-G-1	‘G’ – PBC Corduff - Finglas 1 220_kV cct	Corduff - Finglas 2 220 kV cct	**135%**	**586**	**434**
Summer Peak	N-1-1	Corduff - Woodland 2 220 kV cct & Clonee – Woodland 1 220 kV cct	North Wall – Poolbeg 220 kV cct	**115%**	**380**	**330**

Table 17 *Results of TSSPS Tests for Case 4 – HNC unavailable*

There are overloads for N-1, N-G-1, and N-1-1.

For N-1, the loss of either Clonee – Woodland or Corduff - Woodland 220 kV results in the unacceptable overload of the remaining line for summer peak. For winter peak, these overloads are below 110% and can be reduced post-fault by increasing the output on the remaining generators in North Dublin.

There are unacceptable overloads on Clonee – Woodland or Corduff - Woodland 220 kV circuit for the loss of the other and no remaining options to reduce these pre or post-fault.

For the arrangement (see section 5.1.2) to manage the unavailability of HNC there are unacceptable N-1 overloads on the Corduff – Finglas 220 kV lines should PBC at Shellybanks also be unavailable.

For an N-1-1 involving the loss of Clonee – Woodland and Woodland – Corduff 220 kV lines there are overloads on the North Wall – Poolbeg and Belcamp - Shellybanks 220 kV cables. Only two circuits are left to feed the load in North Dublin (North Wall – Poolbeg and Belcamp - Shellybanks 220 kV cables) along with the two remaining generators (HNC and PBC). This is not enough to feed the expanded load in North Dublin.

5.5.3.3 PBC Unavailable

With all units at PBC, which is connected at Shellybanks 220 kV station, unavailable there is no need to re-arrange the network and the normal layout shown in 5.1.1 is used.

Season	Network Contingency		Overloaded Circuit			
			Circuit	Loading (%)	Loading (MVA)	Rating (MVA)
Winter Peak	N-1	Clonee – Woodland 1 220 kV cct	Corduff - Woodland 2 220 kV cct	**120%**	**641**	**534**
Winter Peak	N-1	Corduff - Woodland 2 220 kV cct	Clonee – Woodland 1 220 kV cct	**122%**	**651**	**534**
Summer Peak	N-1	Clonee – Woodland 1 220 kV cct	Corduff - Woodland 2 220 kV cct	**135%**	**586**	**434**
Summer Peak	N-1	Corduff - Woodland 2 220 kV cct	Clonee – Woodland 1 220 kV cct	**137%**	**595**	**434**
Winter Peak	N-G-1	'G' – HN2 Corduff - Woodland 2 220 kV cct	Clonee – Woodland 1 220 kV cct	**155%**	**828**	**534**
Summer Peak	N-G-1	'G' – HN2 Clonee – Woodland 1 220 kV cct	Corduff - Woodland 2 220 kV cct	**190%**	**825**	**434**
Summer Peak	N-1-1	Poolbeg 220_kV Reactor & Corduff - Woodland 2 220 kV cct	Clonee – Woodland 1 220 kV cct	**160%**	**528**	**330**

Table 18 *Results of TSSPS Tests for Case 4 – PBC unavailable*

As per 5.3.3.1 and 5.5.3.2 there are unacceptable overloads for N-1, N-G-1 and N-1-1. For N-1, the loss of either Clonee – Woodland or Corduff - Woodland 220 kV results in the unacceptable overload of the remaining Corduff - Woodland 220 kV line for summer peak and winter peak.

N-G-1 problems are for the loss of either Clonee – Woodland or Corduff - Woodland 220 kV line (with HN2 also out) which results in the overload of the remaining Corduff - Woodland 220 kV line. These overloads cannot be reduced post-fault by increasing the output on the single remaining generator in North Dublin (HNC) to maximum and there is not enough network capacity to feed the load in North Dublin.

An N-1-1 involving the loss of the Poolbeg 220 kV Inter-Bus Tie Reactor and Corduff - Woodland 220 kV line leads to overloads on the remaining Clonee – Woodland 220 kV line (160%).

5.6 Fault level tests

Single phase to ground fault levels for a busbar fault at Finglas 220 kV substation are shown in the table below. This is the worst fault on the 220 kV system in Dublin and is used to summarise available margins.

Studies were done for screening of maximum fault levels and problems flagged at 90% of allowed Grid Code levels.

X/R ratios greater that 14 are highlighted in green. At those stations with an X/R ratio greater than 14 the TOT RMS break current must be compared against the switchgear rating.

Those stations with short circuit levels greater than 80% of rating are highlighted in red. A longer list of fault levels for important Dublin nodes for each case is shown in the appendix.

				Maximum SC Study						
				1 phase						
Network Arrangement	Node	Voltage	Minimum SC rating (kA)	X/R	Peak Make	% of rating	RMS AC Break	% of rating	TOT RMS Break	% of rating
Normal (*see 5.1.1*)	FINGLAS	220	40	14.1	81.7	82%	30.1	75%	33.5	84%
PBC Tailed with 4 units (*see 5.1.2*)	FINGLAS	220	40	14.1	89.1	89%	32.7	82%	36.5	91%
PBC Tailed with 3 units (see 5.1.2)	FINGLAS	220	40	13.5	82.3	82%	30.2	76%	33.4	84%
Shellybanks 220 kV Coupled with 2 units	FINGLAS	220	40	9.3	87.8	88%	33.5	84%	34.8	87%

Table 19 *Fault Level Results for Finglas 220 kV*

The results show that the network re-arrangements used in this study to manage power flows on the network are acceptable from a fault level perspective but that remaining margins are narrow. This will have an impact on the next phase of optioneering: any solution to capacity shortages that increases system strength could lead to fault level violations. This could either invalidate that solution option or force further mitigations to reduce fault levels at Finglas or elsewhere.

The normal arrangement (see section 5.1.1) has an open point at Shellybanks 220 kV substation with one unit on the north side and two on the south side. All other generators in Dublin are on. Under these circumstances a small margin of 6% remains.

The alternative arrangement (see section 5.1.2) with PBC tailed also maintains the north-south split at Shellybanks 220 kV substation but with all three PBC units on the north side. If all other generators in Dublin are on then this arrangement could be a problem with fault levels exceeding 90%. With one generator in Dublin unavailable and 3 units remaining the arrangement produce fault levels below 90%.

With no north-south split at Shellybanks 220 kV substation and two units on (HN2 and DB1) fault levels are close to 90% but with little margin (2%) left for increasing system strength.

5.7 Summary of network problems

The analysis of the transmission network indicates that there are a number of issues in breach of our Transmission System Security Planning Standards (TSSPS) that must be addressed.

5.7.1 North Dublin 220 kV corridor

Network needs were identified in the corridor of transmission network between the Woodland 400 kV station to the north west of Dublin, the key load and generation centres at Finglas and Corduff 220 kV stations, and load and generation in the city centre at Poolbeg and Shellybanks 220 kV stations.

The network needs are predominantly on the circuits between Corduff 220 kV and Woodland 400 kV stations. This is because much of the new load is located at Corduff (and between Woodland and Corduff) while Woodland is a strong node with EWIC behind it.

Network needs were also identified in the cable circuits between Finglas, and the Poolbeg and Shellybanks 220 kV stations. These needs were more prevalent as availability of generation in the North Dublin network is reduced, or demand in North Dublin increased.

5.7.1.1 TSSPS beaches by case

A summary of the performance of the network between Corduff and Woodland for all of the Cases analysed is shown in Table 20.

Case	N-1	N-G-1	N-1-1	N-LPC
1 Base Case	✓	✗	✓	✓
2 Low Dublin Generation	✗	✗	✗	✗
3 Extra Load	✗	✗	✗	✓
4 Low Dublin Generation and Extra Load	✗	✗	✗	✗

Table 20 *Results of TSSPS Tests for All Cases for the North Dublin Corridor.*

The table shows that for the base case, which requires EirGrid to supply the demand for which it has already issued offers, there is a requirement to reinforce the network. Should generation in Dublin become unavailable, or load increase further, the requirements for reinforcement become more pressing.

6 Plausible scale of solutions

Section 5 describes the drivers for power flows along the North Dublin corridor that are expected to exceed the capacity of the existing transmission network in that corridor.

Plausible candidate solutions to meet the need identified must either add more capacity to the North Dublin corridor or remove the drivers that cause the existing capacity to be used up.

To add capacity to the North Dublin corridor existing circuits must be uprated, additional circuits added, or a combination of these. Capacity could be freed up in the corridor by using power flow control devices to re-route power over those circuits with available capacity.

Adding an additional circuit could also be used to create opportunities to provide ppropriately staged increases in capacity in the future when further drivers for additional capacity in the corridor emerge. For example, a new circuit between Woodland and Corduff could meet the need identified in the short to medium term, but could also permit significant future planned outages on the existing circuits to allow thermal, or voltage, uprates. Constructing a new circuit will have significant challenges. North Dublin is a heavily developed area. There will be limited routes available for either an overhead line or underground cable circuit.

Conversely, uprating an existing circuit, or circuits, between Woodland and Corduff could meet the need. This would be in line with our commitments to make best use of existing assets before considering investing in new assets. Uprating the existing circuits would have its own challenges such as the outages required to carry out the uprating. The ability to respond to future changes in the drivers for additional capacity in the corridor could be limited due to the requirement for further outages.

Alternatively, to avoid needing to increase transmission capacity, it may be possible to develop systems or market products to encourage demand reduction, when needed, to avoid overloading the corridor following an unplanned tripping of an item of transmission equipment.

More permanent and unconventional solutions to avoid needing to increase transmission capacity include encouraging new large-scale, efficient, generation to locate at optimum points in the north Dublin corridor so that it can be used to off-set power flows along the corridor and avoid overloads. Equally, demand could be encouraged to locate elsewhere in the Irish power system where less constrained opportunities are available.

7 Conclusions

The analysis into the system needs in the North Dublin Corridor has highlighted increasing dependence on generation in the Dublin area to ensure continued security of supply if demand continues to grow.

A system need has been identified in the form of a transmission network constraint between Woodland 400 kV station and Corduff 220 kV station. This constraint arises from a case including all four Dublin generators but with a requirement to supply all data centre demand for which EirGrid has issued connection offers (as of August 2017). Under these conditions the existing network is non-compliant with the TSSPS for N-G-1; for an outage of a generator in North Dublin (HNC or HN2) the loss of one Corduff - Woodland 220 kV line overloads the other beyond acceptable post-fault limits. This problem is indicative of a shortage of transmission capacity in the area. To satisfy this need additional capacity between Woodland and Corduff, or the capability to re-route power to use spare capacity elsewhere, is required.

A Less Probable Contingency (LPC) event was identified. If Huntstown 1 at Finglas and Huntstown 2 at Corduff are not dispatched, or both are unavailable, then an unplanned double-circuit tower outage in the area can lead to cascading outages and voltage collapse.

Finally, fault level margins in the North Dublin Corridor are tight. Any reinforcement of the corridor that increases system strength (for example, a 3rd Corduff - Woodland 220 kV circuit) could lead to fault level violations. This will have an impact on optioneering and careful design will be needed.

Appendix 1 – Analysis Results

Appendix 1A – Fault Level Notes

X/R ratios greater that 14 are highlighted in green. At those stations with an X/R ratio greater than 14 the TOT RMS break current must be compared against the switchgear rating.

Those stations with short circuit levels greater than 80% of rating are highlighted in red. The TSSPS stipulates that any switchgear expected to experience a SCL greater than 90% of rating must be replaced or measures put in place to mitigate the short circuit current level. Ratings are included based on planned upgrades assumed complete by 2025.

The 10% margin is to allow for errors in the following key areas:

- **Transformer Taps:** The transformer taps have a significant effect on the fault current that passes through a transformer. With taps on the HV side the apparent impedance of the transformer winding is proportional to the tap ratio squared, as the tap ratio reduces the impedance reduces markedly. In some cases this may result in the impedance at certain tap steps being less than 80% of the nominal tap impedance and the potential fault current may be underestimated. The worst case will be when the tap is set to raise the LV voltage the most. The taps are normally set to provide the required system operating voltage profiles and are unlikely to be at the lowest settings. The margin allows for some variation from the nominal tap transformer impedance in the calculations. A very detailed fault study of a particular busbar should ensure that transformer impedance is correctly accounted for.
- **Uncertainty of Load Make Up:** The make up of certain distribution loads may be more onerous than the assumed 1MVA per MVA of aggregate winter load connected at 10kV or lower. There is not sufficient data available on the make up of load to make specific allocation for all loads. The margin allows for the possibility of some of the distribution industrial load either providing more than 1MVA per MVA of load or being directly connected at 38kV.
- **Plant Tolerances:** A certain allowance for the tolerances in the plant data should also be allowed for in the ratings, both for the impedances of the different network component models and for the switchgear ratings. True switchgear capability may deviate from nameplate due to aging or different conditions in the

network. The switchgear specification tests are based on an X/R ratio of 14 and the actual X/R ratios are likely to be different. The impact of the X/R ratio differences is not clear at present.

Other factors that contribute to the requirement for a margin include:

- Circuit impedance tolerances,
- Calculation methods and algorithms,
- Earthing points on the transmission system, and
- Age of equipment.

Appendix 1B – Fault Level Results: Normal Arrangement

See section 5.1.1

			Maximum SC Study													
			3 phase							1 phase						
Node	Voltage	Minimum SC rating (kA)	X/R	Peak Make	% of rating	RMS AC Break	% of rating	TOT RMS Break	% of rating	X/R	Peak Make	% of rating	RMS AC Break	% of rating	TOT RMS Break	% of rating
BELCAMP	110	25	30.8	37.1	59%	12.6	51%	15.3	61%	28.5	28.9	46%	10.5	42%	12.3	49%
BELCAMP	220	40	12.4	64.9	65%	22.4	56%	24.6	62%	9.9	70.0	70%	26.9	67%	28.1	70%
CARRICKMINES	110	26.2	29.8	36.8	56%	12.3	47%	14.8	57%	23.7	38.3	58%	13.8	53%	15.5	59%
CARRICKMINES	220	40	12.5	58.5	58%	20.4	51%	22.5	56%	8.3	64.3	64%	25.4	64%	26.0	65%
CORDUFF	110	31.5	9.0	59.9	76%	22.2	71%	22.3	71%	10.6	61.6	78%	23.9	76%	24.1	77%
CORDUFF	220	40	14.4	72.9	73%	24.7	62%	28.1	70%	12.3	78.1	78%	29.2	73%	31.7	79%
DUNSTOWN	220	40	8.9	57.8	58%	21.9	55%	22.7	57%	9.2	62.7	63%	24.9	62%	25.8	64%
DUNSTOWN	380	50	5.1	33.5	27%	14.2	28%	14.3	29%	6.2	33.7	27%	14.4	29%	14.5	29%
FIN_URBAN	110	31.5	34.7	41.2	52%	13.7	43%	17.2	55%	30.4	49.6	63%	17.6	56%	20.9	66%
FINGLAS	220	40	15.3	71.8	72%	24.1	60%	27.9	70%	14.1	81.7	82%	30.1	75%	33.5	84%
FIN_RURAL	110	31.5	33.1	41.1	52%	13.2	42%	16.6	53%	27.4	43.0	55%	15.2	48%	17.7	56%
INCH_CITY	110	31.5	28.4	42.8	54%	14.2	45%	17.0	54%	24.6	52.1	66%	18.6	59%	21.1	67%
INCHICORE	220	40	12.3	70.4	70%	24.2	60%	26.5	66%	8.9	77.5	77%	30.0	75%	31.0	78%
INCH_COUNTRY	110	31.5	43.5	43.1	55%	13.9	44%	18.7	59%	32.8	52.4	67%	18.4	58%	22.4	71%
IRISHTOWN	220	40	13.6	66.5	66%	22.7	57%	25.5	64%	10.5	75.8	76%	28.8	72%	30.4	76%
WEST DUBLIN	110	31.5	22.2	49.2	63%	16.9	54%	18.9	60%	23.5	36.3	46%	13.3	42%	14.9	47%
WEST DUBLIN	220	40	9.7	65.8	66%	23.7	59%	24.9	62%	8.5	63.5	64%	25.2	63%	25.9	65%
MAYNOOTH A	110	31.5	10.1	36.7	47%	13.9	44%	14.1	45%	10.9	44.2	56%	17.3	55%	17.4	55%
MAYNOOTH B	220	40	8.5	51.6	52%	19.6	49%	20.2	50%	8.8	47.2	47%	18.9	47%	19.5	49%
MAYNOOTH B	110	31.5	7.4	44.3	56%	17.6	56%	17.6	56%	9.0	42.5	54%	17.1	54%	17.2	55%
MAYNOOTH A	220	40	8.5	54.7	55%	20.8	52%	21.4	54%	8.5	48.0	48%	19.3	48%	19.8	50%
POOLBEG	110	40	27.1	43.4	43%	14.6	36%	17.1	43%	21.4	52.0	52%	18.8	47%	20.7	52%
POOLBEG NORT	220	31.5	13.1	63.5	81%	21.9	69%	24.3	77%	6.6	55.2	70%	22.7	72%	22.9	73%
POOLBEG	110	40	27.0	43.3	43%	14.5	36%	17.1	43%	21.4	51.9	52%	18.8	47%	20.6	52%
POOLBEG SOUT	220	31.5	12.1	64.9	82%	22.5	72%	24.6	78%	8.8	66.1	84%	25.9	82%	26.7	85%
SHELLYBANKS	220	40	12.8	63.2	63%	21.8	55%	24.2	60%	8.0	60.4	60%	24.0	60%	24.5	61%
SHELLYBANKS	220	40	13.2	63.7	64%	21.9	55%	24.4	61%	9.1	70.4	70%	27.3	68%	28.3	71%
SHELLYBANKSB	220	40	13.2	63.7	64%	21.9	55%	24.4	61%	9.1	70.4	70%	27.3	68%	28.3	71%
WOODLAND	220	40	11.7	75.1	75%	27.2	68%	29.3	73%	11.7	74.1	74%	28.5	71%	30.5	76%
WOODLAND	380	40	11.4	44.3	44%	16.6	41%	17.8	44%	11.2	45.1	45%	17.6	44%	18.7	47%

Appendix 1C – Fault Level Results: Shellybanks Tailed Arrangement with 4 units ON in Dublin

See section 5.1.2

			Maximum SC Study													
			3 phase							1 phase						
Node	Voltage	Minimum SC rating (kA)	X/R	Peak Make	% of rating	RMS AC Break	% of rating	TOT RMS Break	% of rating	X/R	Peak Make	% of rating	RMS AC Break	% of rating	TOT RMS Break	% of rating
BELCAMP	110	25	31.2	37.7	60%	12.8	51%	15.6	62%	29.8	29.4	47%	10.7	43%	12.5	50%
BELCAMP	220	40	12.1	68.7	69%	23.6	59%	25.9	65%	10.0	75.3	75%	28.8	72%	30.2	75%
CARRICKMINES	110	26.2	26.8	35.4	54%	11.9	45%	14.0	53%	22.1	36.9	56%	13.4	51%	14.8	56%
CARRICKMINES	220	40	11.4	52.5	52%	18.7	47%	20.1	50%	8.2	57.3	57%	22.7	57%	23.3	58%
CORDUFF	110	31.5	9.2	60.8	77%	22.6	72%	22.7	72%	10.8	62.3	79%	24.2	77%	24.4	78%
CORDUFF	220	40	14.3	78.5	78%	26.5	66%	30.2	75%	12.2	83.0	83%	31.1	78%	33.6	84%
DUNSTOWN	220	40	8.9	56.3	56%	21.4	53%	22.1	55%	9.2	33.5	33%	24.4	61%	25.2	63%
DUNSTOWN	380	50	5.1	33.2	27%	14.1	28%	14.1	28%	6.2	33.5	27%	14.3	29%	14.4	29%
FIN_URBAN	110	31.5	36.2	42.1	53%	14.0	44%	17.7	56%	31.4	50.5	64%	17.9	57%	21.5	68%
FINGLAS	220	40	15.6	78.6	79%	26.1	65%	30.5	76%	14.1	89.1	89%	32.7	82%	36.5	91%
FIN_RURAL	110	31.5	34.5	41.9	53%	15.5	49%	18.1	58%	28.2	43.7	55%	15.5	49%	18.1	58%
INCH_CITY	110	31.5	25.7	41.5	53%	13.9	44%	16.1	51%	23.2	50.6	64%	18.1	58%	20.3	64%
INCHICORE	220	40	11.2	63.6	64%	22.2	56%	23.9	60%	9.3	70.1	70%	27.2	68%	28.2	70%
INCH_COUNTRY	110	31.5	37.3	41.8	53%	13.6	43%	17.5	56%	30.2	51.0	65%	17.9	57%	21.4	68%
IRISHTOWN	220	40	11.9	56.9	57%	20.0	50%	21.7	54%	8.8	63.0	63%	24.7	62%	25.4	64%
WEST DUBLIN	110	31.5	21.2	48.1	61%	16.5	53%	18.3	58%	23.1	35.7	45%	13.1	42%	14.6	46%
WEST DUBLIN	220	40	9.5	62.0	62%	22.5	56%	23.5	59%	8.7	60.6	61%	24.0	60%	24.7	62%
MAYNOOTH A	110	31.5	10.0	36.4	46%	13.8	44%	13.9	44%	10.8	43.8	56%	17.1	54%	17.3	55%
MAYNOOTH B	220	40	8.5	50.0	50%	19.0	48%	19.6	49%	8.8	46.1	46%	18.5	46%	19.0	48%
MAYNOOTH B	110	31.5	7.3	44.2	56%	17.6	56%	17.6	56%	8.9	42.4	54%	17.1	54%	17.1	54%
MAYNOOTH A	220	40	8.4	53.6	54%	20.4	51%	21.0	52%	8.5	47.3	47%	19.1	48%	19.6	49%
POOLBEG	110	40	25.4	42.4	42%	14.2	36%	16.5	41%	20.8	50.9	51%	18.4	46%	20.1	50%
POOLBEG NORT	220	31.5	12.7	60.9	77%	21.2	67%	23.4	74%	6.4	53.8	68%	22.3	71%	22.5	71%
POOLBEG	110	40	25.3	42.3	42%	14.2	35%	16.4	41%	20.7	50.8	51%	18.4	46%	20.1	50%
POOLBEG SOUT	220	31.5	11.3	59.4	75%	20.9	66%	22.5	72%	9.2	61.4	78%	24.0	76%	24.8	79%
SHELLYBANKS	220	40	8.8	53.3	53%	19.4	49%	20.1	50%	7.6	57.7	58%	23.1	58%	23.5	59%
SHELLYBANKS	220	40	11.7	59.9	60%	21.1	53%	22.8	57%	25.0	27.6	28%	10.2	25%	12.8	32%
SHELLYBANKSB	220	40	8.8	53.3	53%	19.4	49%	20.1	50%	7.6	57.7	58%	23.1	58%	23.5	59%
WOODLAND	220	40	11.4	76.1	76%	27.6	69%	29.7	74%	11.5	74.8	75%	28.9	72%	30.8	77%
WOODLAND	380	40	11.4	44.3	44%	16.6	42%	17.8	44%	11.2	45.1	45%	17.6	44%	18.7	47%

Appendix 1D – Fault Level Results: Shellybanks Tailed Arrangement with 3 units ON in Dublin

See section 5.1.2

			Maximum SC Study													
			3 phase							1 phase						
Node	Voltage	Minimum SC rating (kA)	X/R	Peak Make	% of rating	RMS AC Break	% of rating	TOT RMS Break	% of rating	X/R	Peak Make	% of rating	RMS AC Break	% of rating	TOT RMS Break	% of rating
BELCAMP	110	25	29.9	36.4	58%	12.3	49%	14.8	59%	29.0	28.6	46%	10.4	41%	12.1	49%
BELCAMP	220	40	11.9	63.2	63%	21.6	54%	23.6	59%	10.0	70.5	71%	26.9	67%	28.2	70%
CARRICKMINES	110	26.2	26.5	35.1	54%	11.8	45%	13.8	53%	22.0	36.5	56%	13.2	51%	14.6	56%
CARRICKMINES	220	40	11.4	51.8	52%	18.4	46%	19.8	49%	8.2	56.6	57%	22.4	56%	23.0	57%
CORDUFF	110	31.5	8.9	60.8	77%	21.7	69%	21.8	69%	10.5	60.7	77%	23.6	75%	23.8	76%
CORDUFF	220	40	13.1	69.8	70%	23.6	59%	26.3	66%	11.5	76.3	76%	28.6	71%	30.6	77%
DUNSTOWN	220	40	8.9	55.7	56%	21.1	53%	21.8	55%	9.2	33.2	33%	24.1	60%	25.0	62%
DUNSTOWN	380	50	5.1	32.9	26%	14.0	28%	14.0	28%	6.2	33.2	27%	14.2	28%	14.3	29%
FIN_URBAN	110	31.5	34.0	40.5	51%	13.4	43%	16.8	53%	29.9	48.8	62%	17.3	55%	20.5	65%
FINGLAS	220	40	14.7	71.3	71%	23.7	59%	27.2	68%	13.5	82.3	82%	30.2	75%	33.4	83%
FIN_RURAL	110	31.5	32.4	40.6	52%	15.0	48%	17.4	55%	27.1	42.5	54%	15.0	48%	17.4	55%
INCH_CITY	110	31.5	25.5	41.0	52%	13.7	43%	15.9	50%	23.0	50.1	64%	17.9	57%	20.0	64%
INCHICORE	220	40	11.2	62.6	63%	21.8	54%	23.4	59%	9.3	69.2	69%	26.7	67%	27.7	69%
INCH_COUNTRY	110	31.5	36.7	41.4	53%	13.4	42%	17.2	55%	29.8	50.5	64%	17.7	56%	21.1	67%
IRISHTOWN	220	40	11.8	56.1	56%	19.7	49%	21.4	53%	8.8	62.2	62%	24.3	61%	25.1	63%
WEST DUBLIN	110	31.5	21.0	47.5	60%	16.3	52%	18.0	57%	23.0	35.4	45%	13.0	41%	14.4	46%
WEST DUBLIN	220	40	9.5	61.0	61%	22.0	55%	23.0	58%	8.7	59.8	60%	23.6	59%	24.3	61%
MAYNOOTH A	110	31.5	10.0	36.1	46%	13.7	43%	13.8	44%	10.8	43.5	55%	17.0	54%	17.2	54%
MAYNOOTH B	220	40	8.5	49.4	49%	18.7	47%	19.3	48%	8.8	45.6	46%	18.3	46%	18.8	47%
MAYNOOTH B	110	31.5	7.3	43.5	55%	17.2	55%	17.3	55%	8.9	41.8	53%	16.8	53%	16.9	54%
MAYNOOTH A	220	40	8.4	52.5	53%	19.9	50%	20.5	51%	8.5	46.5	47%	18.7	47%	19.2	48%
POOLBEG	110	40	25.1	42.5	42%	14.2	36%	16.4	41%	20.6	51.0	51%	18.4	46%	20.1	50%
POOLBEG NORT	220	31.5	12.8	57.2	73%	19.8	63%	21.9	69%	6.6	51.5	65%	21.2	67%	21.4	68%
POOLBEG	110	40	25.1	42.4	42%	14.2	35%	16.4	41%	20.6	51.0	51%	18.4	46%	20.1	50%
POOLBEG SOUT	220	31.5	11.2	58.5	74%	20.5	65%	22.1	70%	9.1	60.6	77%	23.6	75%	24.5	78%
SHELLYBANKS	220	40	9.1	50.2	50%	18.1	45%	18.8	47%	7.8	54.9	55%	21.9	55%	22.3	56%
SHELLYBANKS	220	40	11.9	56.3	56%	19.6	49%	21.4	53%	24.6	26.8	27%	9.8	25%	12.3	31%
SHELLYBANKSB	220	40	9.1	50.2	50%	18.1	45%	18.8	47%	7.8	54.9	55%	21.9	55%	22.3	56%
WOODLAND	220	40	11.4	73.3	73%	26.4	66%	28.4	71%	11.5	72.6	73%	27.9	70%	29.8	75%
WOODLAND	380	40	11.2	43.8	44%	16.4	41%	17.5	44%	11.1	44.6	45%	17.5	44%	18.5	46%

Appendix 1E – Fault Level Results: Shellybanks Coupled Arrangement with 2 units ON in Dublin

See 5.3.3.4.2 – **Error! Reference source not found.**

			Maximum SC Study													
			3 phase							1 phase						
Node	Voltage	Minimum SC rating (kA)	X/R	Peak Make	% of rating	RMS AC Break	% of rating	TOT RMS Break	% of rating	X/R	Peak Make	% of rating	RMS AC Break	% of rating	TOT RMS Break	% of rating
BELCAMP	110	25	26.1	37.2	59%	12.8	51%	14.8	59%	26.4	29.3	47%	10.7	43%	12.3	49%
BELCAMP	220	40	9.3	69.4	69%	24.4	61%	25.5	64%	7.8	80.8	81%	31.7	79%	32.4	81%
CARRICKMINES	110	26.2	27.0	37.0	56%	12.4	47%	14.6	56%	21.0	38.5	59%	14.0	54%	15.4	59%
CARRICKMINES	220	40	10.5	62.3	62%	21.9	55%	23.3	58%	6.7	68.8	69%	27.9	70%	28.2	71%
CORDUFF	110	31.5	8.8	58.3	74%	21.7	69%	21.8	69%	10.3	60.4	77%	23.5	75%	23.7	75%
CORDUFF	220	40	10.4	73.3	73%	25.5	64%	27.1	68%	9.4	80.1	80%	30.8	77%	32.0	80%
DUNSTOWN	220	40	8.6	56.1	56%	21.3	53%	21.9	55%	8.9	61.1	61%	24.3	61%	25.1	63%
DUNSTOWN	380	50	5.1	32.3	26%	13.7	27%	13.7	27%	6.1	32.8	26%	14.0	28%	14.1	28%
FIN_URBAN	110	31.5	28.0	40.8	52%	13.7	44%	16.3	52%	25.5	49.3	63%	17.7	56%	20.1	64%
FINGLAS	220	40	10.4	74.1	74%	25.6	64%	27.2	68%	9.3	87.8	88%	33.5	84%	34.8	87%
FIN_RURAL	110	31.5	26.8	40.7	52%	13.3	42%	15.7	50%	23.7	42.6	54%	15.2	48%	17.1	54%
INCH_CITY	110	31.5	25.1	42.0	53%	14.0	45%	16.2	52%	21.7	51.2	65%	18.4	58%	20.3	64%
INCHICORE	220	40	10.4	68.5	69%	23.7	59%	25.3	63%	7.0	76.1	76%	30.4	76%	30.8	77%
INCH_COUNTRY	110	31.5	36.3	42.3	54%	13.7	44%	17.6	56%	27.9	51.5	65%	18.2	58%	21.3	68%
IRISHTOWN	220	40	10.7	76.0	76%	26.0	65%	27.9	70%	8.7	89.5	89%	34.4	86%	35.5	89%
WEST DUBLIN	110	31.5	20.4	47.9	61%	16.5	52%	18.1	57%	21.7	35.5	45%	13.1	41%	14.4	46%
WEST DUBLIN	220	40	9.1	62.5	62%	22.6	56%	23.5	59%	7.8	61.1	61%	24.5	61%	25.0	62%
MAYNOOTH A	110	31.5	10.1	36.1	46%	13.7	43%	13.8	44%	10.8	43.5	55%	17.0	54%	17.2	54%
MAYNOOTH B	220	40	8.3	49.9	50%	18.9	47%	19.4	49%	8.5	45.9	46%	18.5	46%	19.0	47%
MAYNOOTH B	110	31.5	7.3	42.8	54%	17.0	54%	17.0	54%	8.9	41.4	53%	16.7	53%	16.7	53%
MAYNOOTH A	220	40	8.4	51.1	51%	19.3	48%	19.9	50%	8.3	45.8	46%	18.5	46%	18.9	47%
POOLBEG	110	40	23.9	42.3	42%	14.2	36%	16.3	41%	19.3	50.7	51%	18.4	46%	19.9	50%
POOLBEG NORT	220	31.5	10.3	74.9	95%	25.8	82%	27.4	87%	5.6	60.1	76%	25.4	81%	25.5	81%
POOLBEG	110	40	23.8	42.2	42%	14.2	36%	16.2	41%	19.3	50.7	51%	18.4	46%	19.9	50%
POOLBEG SOUT	220	31.5	10.1	61.2	78%	21.6	68%	22.8	72%	7.4	63.1	80%	25.3	80%	25.7	81%
SHELLYBANKS	220	40	10.7	75.7	76%	25.9	65%	27.7	69%	8.8	89.1	89%	34.2	86%	35.3	88%
SHELLYBANKS	220	40	10.7	75.7	76%	25.9	65%	27.7	69%	8.8	89.1	89%	34.2	86%	35.3	88%
SHELLYBANKSB	220	40	10.7	75.7	76%	25.9	65%	27.7	69%	8.8	89.1	89%	34.2	86%	35.3	88%
WOODLAND	220	40	11.0	70.5	71%	25.5	64%	27.3	68%	11.2	70.9	71%	27.4	68%	29.1	73%
WOODLAND	380	40	11.0	42.8	43%	16.0	40%	17.1	43%	10.9	44.0	44%	17.2	43%	18.2	46%