Options Report
Part B
Capital Project 0966

March 2019

EIRGRID

Revision Table:

Revision	Issue Date	Description
01	26-10-2018	Issued for Gateway 2 Governance in Framework for Grid Development – Step 2
02	2-04-2019	Section 5 updated after 10-week consultation period ended 4th February 2019. Appendix 4G updated to reflect short circuit values. Correction to typographical errors and clarifications throughout document.

1 Table of Contents

2 Introduction

EirGrid follow a six step approach when we develop and implement the best performing solution option to any identified transmission network problem. This six step approach is described in the document 'Have Your Say' published on EirGrid's website[1] and is known as the framework for developing the grid. The six steps are shown on a high-level in Figure 1. Each step has a distinct purpose with defined deliverables.

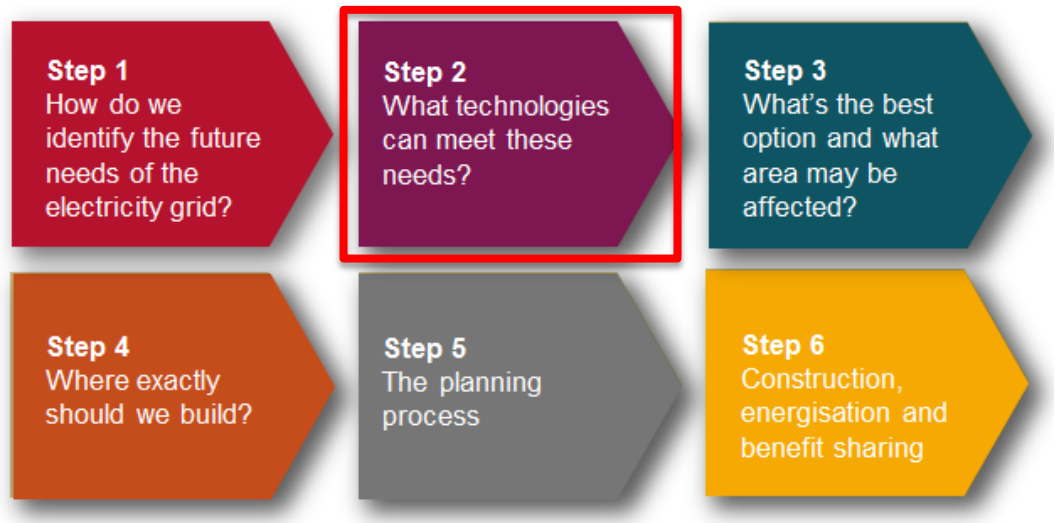


Figure 1 *High Level Project Development Process*

The transmission network problem was identified and described in previous Step 1 and was documented in the Need Report.

The need, in this case, involves a transmission network problem regarding the transfer of power across the existing 400 kV transmission network from west to east and the transfer of this power within the transmission network as it reaches the east coast. The issues encountered involve on a high level capacity and voltage.

In Step 2 there are two reports to be delivered, namely Options Report Part A and Options Report Part B. The Options Report Part A, covers the aspects that will be considered when creating the long list of options and the first refinement of this list. The outcome of the second part of refinement of the list is presented in Options Report Part B (this document).

[1] http://www.eirgridgroup.com/the-grid/have-your-say/

3 Process followed and criteria

3.1 Description of process

The transmission network problem was identified and described in previous Step 1 and documented in the Need Report. Following on from Step 1, the process of identifying viable technology solution options starts. This involves a rigorous process spanning over two steps namely, Step 2 and Step 3. The outcome of Step 2 is a list of best performing solution options which will be taken to Step 3 for further investigation and evaluation. At the end of Step 3 we will have a best performing solution option which will be developed for construction and energisation. This report details the outcome of the second part of the refinement of the long list in Step 2.

Figure 2 provides an overview of the process and different tasks in Step 2. The first three tasks were covered in Options Report Part A. The outcome of these three first tasks was a refined long list.

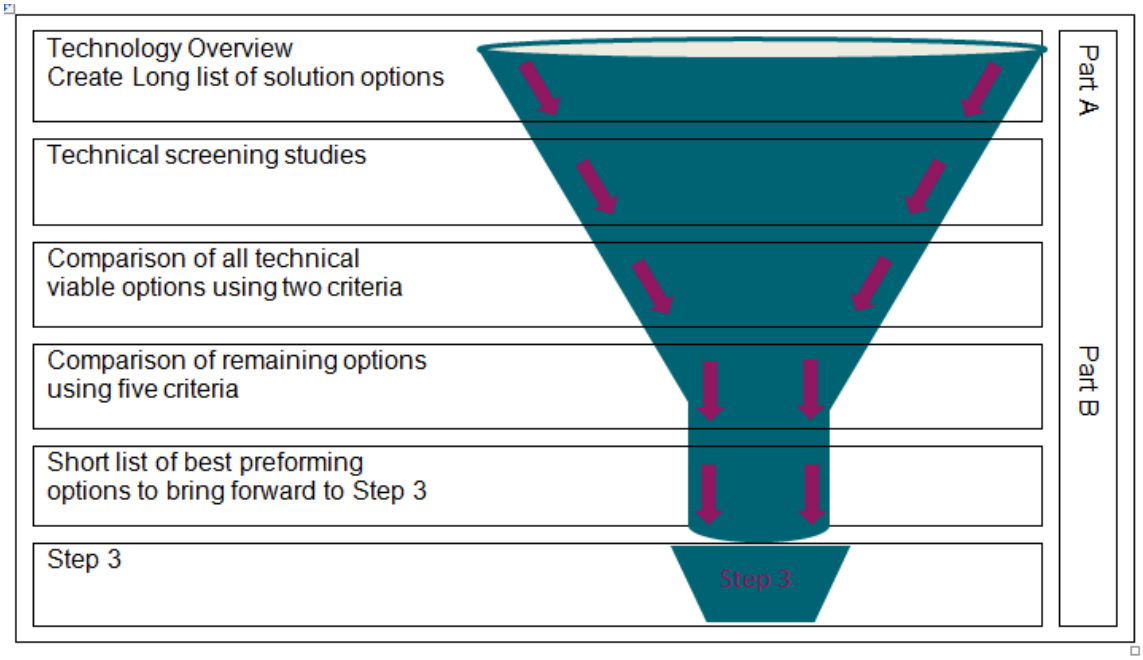


Figure 2 *Illustration of the process of developing of options in Step 2*

The list is further refined in Step 2, this time using a multi-criteria comparison against five criteria namely, technical performance, economic performance, environmental aspects, deliverability aspects and socio-economic aspects. Each remaining option is assessed against the five criteria. This is discussed in Section 7 Detailed evaluation of the options. The outcome of Step 2 is a short list of solution options which will be taken to Step 3 for further investigation and evaluation.

3.2 Criteria used for comparison of remaining options

The second time the performance matrix is used in Step 2, each remaining option is assessed against the five criteria. The five criteria are technical performance, economic performance, environmental aspects, deliverability aspects and socio-economic aspects. Descriptions of the five criteria are outlined below. It should be noted that the assessments provided are for comparison against each other and not absolute assessments of the individual options.

3.2.1 Technical performance

In Part B in Step 2 the technical performance criteria is based on compliance with Transmission System Security and Planning Standards (TSSPS) and compliance with current transmission investment policies. Only options that meet the minimum technical requirements set out in the TSSPS qualify for consideration in Step 2 Part B. Options which extend or enhance technical performance margins beyond minimum acceptable levels are favoured over others.

The options will be assessed against five technical performance criteria to be able to distinguish between their individual technical performances. The technical criteria in Step 2 Part B relate to the needs identified and are thermal overload, voltage phase angle, reactive support requirements, short circuit performance and performance during maintenance conditions. A short description of these is given below.

3.2.1.1 Thermal overload criteria

The options are assessed for compliance with the Transmission System Security and Planning Standards (TSSPS). If thermal overload violations are identified additional potential reinforcements will be added to the options until the enhanced option fully meets the TSSPS. For this technical criterion we have assessed the options based on how many additional thermal overloads are remaining after the option has been added. This will provide an indication of how the options are performing in terms of adding thermal capacity.

3.2.1.2 Voltage phase angle

The options are assessed for compliance with the Operating Security Standards (OSS), which EirGrid is required to comply with in its licence. The OSS states that EirGrid should maintain a voltage phase angle of 40 degrees or below. The need analysis in Step 1 identified a voltage phase angle difference above 40 degrees between Woodland and Oldstreet stations when the Woodland – Oldstreet 400 kV circuit was opened. Only options that remain within the requirement set out in the OSS qualify for consideration in Step 2 Part B. All options therefore reduce the voltage phase angle to 40 degrees or less.

The options will be assessed on how much they can reduce this angle difference for the above described event. Angle differences are influenced by, among other things, the relative impedances of the new network reinforcements suggested.

3.2.1.3 Reactive support requirements

The needs assessment (Step 1) for CP0966 identified voltage stability problems. None of the basic options alone meet this need. The requirement for reactive support has been analysed as part of the solution options to solve the voltage instability.

To determine the amount of reactive support required for each of the solution options we used two criteria. The first criterion is to meet the need based on the assumptions set out in Step 1. In Step 1 the assumptions were that approximately 900 MW of additional demand was connected in the counties Kildare, Meath and Dublin. This was based on executed and offered connection agreements at that point in time.

The second criterion is to meet further demand on the East coast that could materialise in the future. Ireland is currently experiencing an increased interest in connecting large scale demand on the East coast and the options were assessed based on their capability of accommodating this. Given the interest in connecting large scale demand on the East coast an extra 500 MW of demand, on top to the 900 MW mentioned earlier, was deemed prudent for assessing the options against.

3.2.1.4 Short circuit performance

The options are assessed based on the scale that they improve or exacerbate the existing short circuits levels in existing stations. Additional circuits and/or transformers connected into stations will create another path for the fault current to flow into the station and as such the short circuit levels will increase in the station. Similarly, if circuits are removed the number of paths for the fault current to flow has reduced and as such the short circuit levels will decrease in the station.

3.2.1.5 Performance during maintenance conditions

The options are assessed based on their requirement for additional reinforcements to keep the network within standards following a subsequent loss of plant and equipment whilst another is out for planned maintenance. It should be noted that investments resulting from violations during planned maintenance are subject to an economic appraisal of the value in solving the identified problem compared to constraining generation. Before we would bring these forward as projects we will individually appraise whether each of these reinforcements could be financially justified. To ensure value for money, we will defer a decision until much closer to the required commissioning date of the best performing option. This will allow us to take account of new requirements for

each reinforcement, which may include both local and regional needs which could have emerged in the meantime. As such, for the purpose of this assessment in Step 2, we have only assessed the number of indicated violations of thermal capacity for each option. It should be noted that these possible additional reinforcements are not included in the full solution list of the options in Section 4.3.

3.2.2 Economic performance

In Part B in Step 2, the economic performance is based on estimated Total Project Cost (TPC) for each option for comparison purposes. The TPC will comprise both estimated capital costs and an estimated cost for the Transmission System Operator (TSO) element for development of the options.

The primary source for capital cost estimates have been developed with input from the Transmission Asset Owner (TAO) and are based on desktop designs and costings for similar works. The capital cost includes all items to achieve a fully compliant solution with Transmission System Security and Planning Standards (TSSPS), but are excluding reinforcements driven by maintenance conditions as discussed in section 3.2.1.5. Where capital costs were not available for a particular technology the best, most recent estimates or quotes from manufacturers or assumed costs based on EirGrid or international experience have been used.

The TSO cost can be described as the cost for the Transmission System Operator to develop the project during the planning and construction phase. The cost comprise among other things, project management, wayleaving and landowner engagements and cost attributed to developing the planning application. The estimated cost is based on experience of developing previous projects.

3.2.3 Environmental

This is a high-level consideration of environmental impacts in the context of the project. It is largely based on a desktop study. Under this criterion, consideration is given to biodiversity, soil and water, climatic factors, material assets and noise. Note that cultural heritage, landscape and visual are examined under the heading of Socio-economic and not repeated in this section.

3.2.4 Deliverability

Deliverability captures timelines as well as engineering and planning risks which could extend delivery timescales and costs. A high level assessment of the impacts of any planned transmission equipment outages required to carry out the necessary work is also carried out.

3.2.5 Socio-Economic

This is a high-level consideration of social impacts in the context of the project. It is largely based on a desktop study. Under this criterion consideration is given to settlement and communities; recreation and tourism; landscape and visual; and cultural heritage and other relevant issues.

3.3 Scale used to assess each criteria

The effect on each criteria parameter is presented along a range from “more significant”/”more difficult”/“more risk” to “less significant”/”less difficult”/“less risk”. The following scale is used to illustrate each criteria parameter:

More significant/difficult/risk Less significant/difficult/risk

In the text this scale is quantified by text for example mid-level/moderate (Dark Green), low-moderate (Green), low (Cream), high-moderate (Blue) or high (Dark Blue).

4 Development of a short list

In Step 2, the identified list of options are refined twice with the aim to establish a short list of best performing solution options to bring forward for further investigation in Step 3. The outcome from the first part of the refinement of the long list is presented in the Options Report Part A. The second time the list is refined, each remaining option will be assessed against the five criteria. The summary of this assessment is presented in this section and further details are given in section 7, Detailed evaluation of options.

4.1 Options brought forward from Part A of Step 2

The outcome of first part of the refinement of the long list is presented in the Options Report Part A. This assessment identified five solution options using three different technologies that would address the need identified. The technologies were:

- Overhead line (OHL)
- Underground cable (UGC)
- Up-voltage technology
  This will maximise existing infrastructure by modifying existing 220 kV towers to towers of similar scale and size, but will be capable of carrying a 400 kV conductor.

All the five remaining solution options reinforce the transmission network between existing Dunstown station in County Kildare and Woodland station in County Meath. The five solution options in the refined list were:

- Up-voltage existing 220 kV circuits to 400 kV to create new Dunstown – Woodland 400 kV overhead line (OHL)
- New Dunstown – Woodland 400 kV overhead line (OHL)
- New Dunstown – Woodland 220 kV overhead line (OHL)
- New Dunstown – Woodland 220 kV underground cable (UGC)
- New Dunstown – Woodland 400 kV underground cable (UGC)

4.2 Summary of assessment of remaining options

The five remaining solution options were assessed against the five criteria. Table 1 provides a summary of the performance of each option against the five evaluation criteria. The details of each option are presented in section 7, Detailed evaluation of options.

The outcome of the multi criteria assessment is that all except one of the options will be brought forward into step 3 for further more detailed assessment.

Options	Technical Performance	Economic Performance	Environmental	Deliverability	Socio-economic	Combined Performance in Step 2 Part B
Upvoltage 220 kV to 400 kV						
New 400 kV OHL						
New 220 kV OHL						
New 220 kV UGC						
New 400 kV UGC						

Table 1 *Overall comparison of options using five criteria in Step 2 Part B*

The options brought forward to Step 3 are:

- Up-voltage existing 220 kV circuits to 400 kV to create new Dunstown – Woodland 400 kV overhead line (OHL)
- New Dunstown – Woodland 400 kV overhead line (OHL)
- New Dunstown – Woodland 220 kV underground cable (UGC)
- New Dunstown – Woodland 400 kV underground cable (UGC)

This means that three technologies are still being investigated to come up with the best performing solution option. In Step 3, these technologies and the options using them will be investigated in even more detail. In Step 3 the five main criteria are broken down into sub-criteria, which the remaining options will be assessed against. It should be recognised that two of these technologies have features and technical aspects which have not yet been studied or investigated.

The up-voltage technology is a new innovation that has not been used in the Irish transmission system previously. This presents its own opportunities and challenges. In Step 3 we will be able to investigate these in more detail.

The underground cable technology (AC cable) requires very detailed specific technical analysis to determine if they are technically feasible. These studies include analysis to investigate Temporary Over Voltages (TOV) and harmonic distortion among other things. Previously, for other projects, the acceptable length of underground cable (AC) has varied depending on voltage and location of the cable within the network. It should be recognised that analysis for other projects has indicated that long lengths of AC 400 kV underground cable cannot be accommodated in the Irish transmission network. A full investigation into these aspects will be completed in Step 3 for both remaining underground cable options. The result of these analyses may lead to that some options are not technically feasible or that further investments are required to accommodating them.

4.3 Recommended short list of best performing options

The options in the refined list were assessed against the five criteria. This resulted in four solution options being brought forward for more detailed analysis in Step 3. All options involve a suite of transmission network reinforcements centred on strengthening the network between existing Dunstown 400 kV station in County Kildare and Woodland 400 kV station in County Meath. There are some common requirements for all options and for the 220 kV underground cable option there are additional reinforcements required. The four options are:

1. Up-voltage option
    - Up-voltage some of the existing 220 kV circuits between existing Dunstown 400 kV station and Woodland 400 kV station. Using a new technology which would enable the existing 220 kV towers to be modified and the 220 kV conductors replaced with 400 kV conductor to create a new Dunstown – Woodland 400 kV circuit. The circuits selected to achieve this are Gorman – Maynooth 220 kV circuit and the Dunstown – Maynooth 2 220 kV circuit.
2. 400 kV OHL option
    - Construction of a new 400 kV overhead line linking Dunstown 400 kV station to Woodland 400 kV station.
3. Underground cable (220 kV or 400 kV)

- Construction of a new 220 kV or 400 kV underground cable linking Dunstown 400 kV station to Woodland 400 kV station.

If a 220 kV cable is the best performing option then, the following additional reinforcements are required:

- Uprating of the Cashla – Prospect 220 kV overhead line
- Uprating of the Killonan – Shannonbridge 220 kV overhead line
- Woodland 220 kV station would be required to be operated “split” in order to prevent thermal overloading of the new 220 kV cable for an unplanned loss of a circuit

4. Common requirements for all options:
    - Uprating of the Bracklone – Portlaoise 110 kV overhead line
    - Dynamic reactive support device in area of Inchicore station rated at approximately ±250 Mvar

5 Stakeholder Engagement

The aim of stakeholder engagement in Step 2 is to transparently communicate our findings so far in the project to key stakeholders and receive feedback on chosen technologies and refined short list.

In order to ensure appropriate stakeholder feedback and inform our decision-making process during Step 2 on Capital Project 966, EirGrid have identified key strategic stakeholders in the study area. This engagement has enabled us to understand the spatial and economic planning that is underway at local and regional authority level, as well as the potential requirements for future investments by large energy users in the area. It has also allowed us to brief key stakeholders in the area, and to garner their view of the opportunities and challenges that exist for the project, as well as receive feedback on chosen technologies and the refined short list.

The stakeholder engagement for Capital Project 966 in Step 2 was divided into two phases, phase A and phase B. In phase A, we have consulted with relevant stakeholders such as the Government Departments, Meath and Kildare County Council Senior Executives, the IDA and the Eastern and Midlands Regional Assembly. This phase was completed between March and June 2018.

In phase B, a 10-week consultation period started in November 2018 and finished in early February 2019. The consultation period covered a broad range of stakeholder engagement with the general public, local communities and their elected representatives. They had the opportunity to provide feedback in relation to the assessment carried out to date and the solutions to be brought forward for further consideration in Step 3.

No additional technology options were either removed or added as a result of the consultation period. Most of the responses covered personal views of preferences for one or other technologies. Mostly these preferences were in relation to the underground technology or the up-voltage technology. Many stakeholders also welcomed the opportunity for early engagement.

As part of the 10-week consultation period the following tasks were carried out:

- published project related material on the project website, including reports and project brochures;
- issued a press statement to the media;

- communicated details of our work on this project to local elected representatives and offering briefings; and,
- engaged with the Public Participation Networks in Kildare and Meath to provide information on the project to local community groups in the region.

6 Assessment of project complexity

Each project may be of a different scale and/or complexity. To reflect the unique features of each project, the framework for grid development introduced three categories of projects, called Tiers.

The Tier of a project indicates the required level of governance, external consultation and engagement, social impact assessment and analysis.

To decide the Tier for a project a number of factors have to be considered. An assessment should consider different aspects such as project complexity, customer impact, deliverability, health and safety, legacy issues, operational risks, stakeholder engagement, and technical risks.

Capital Project 966 has been assigned a Tier 3 which is the most complex category with the highest level of governance. This is based on the most complex remaining option. In this case, it is a new 400 kV overhead line. New linear projects have the potential to traverse many different stakeholders and as such increasing the number of stakeholders that need to be considered. As well as this, the potential impact on society and the environment also require significant investigations and consideration. For this reason this project has been assigned a Tier 3.

7 Detailed evaluation of options

This section will describe in detail the assessment of each of the five remaining options against the five criteria. The criteria are described in section 3.2 and the below assessment of the options require an understanding of these. All remaining solution options reinforce the transmission network between existing Dunstown and Woodland stations.

7.1 Up-voltage existing 220 kV circuits to 400 kV OHL circuit

7.1.1 Description of option

This option involves a suite of transmission network reinforcements centred on strengthening the network between existing Dunstown 400 kV station in County Kildare and Woodland 400 kV station in County Meath. These consist of:

- Up-voltage some of the existing 220 kV circuits between existing Dunstown 400 kV station and Woodland 400 kV station. Using a new technology which would enable the existing 220 kV towers to be modified and the 220 kV conductors replaced with 400 kV conductor to create a new Dunstown – Woodland 400 kV circuit. The circuits selected to achieve this are Gorman – Maynooth 220 kV circuit and the Dunstown – Maynooth 2 220 kV circuit.
- Uprating of the Bracklone – Portlaoise 110 kV overhead line.
- Dynamic reactive support device in area of Inchicore station rated at approximately ±250 Mvar.

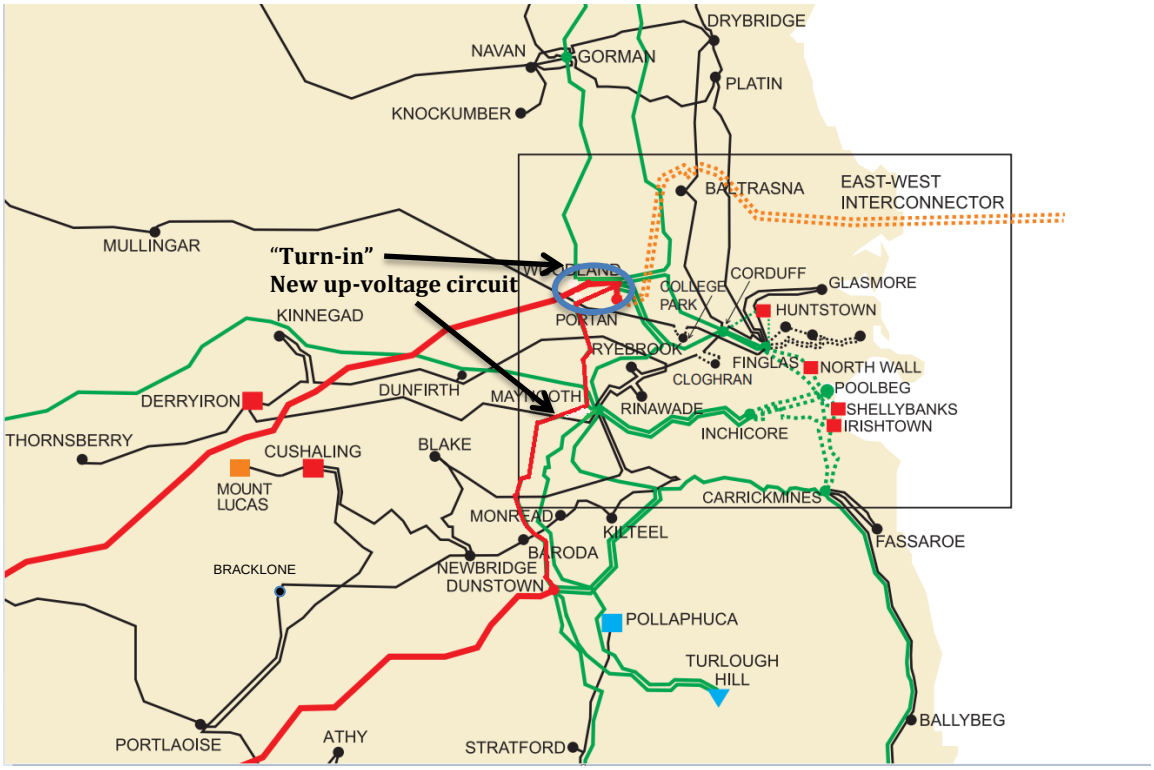


Figure 3 *Transmission system map showing the option to up-voltage existing 220 kV circuits to 400 kV OHL (the up-voltaged lines between Dunstown and Woodland 400kV stations are shown in red, in a north southerly direction following the existing paths of Gorman – Maynooth and Maynooth – Woodland 220 kV circuits).*

7.1.2 Selection of existing 220 kV circuits to use for the up-voltage option

This option uses existing 220 kV circuits to create a new 400 kV circuit between Woodland and Dunstown stations. There are a number of existing 220 kV circuits between Woodland and Dunstown stations which would be suitable for the up-voltage technology. To be able to select the best candidate, all these existing 220 kV circuits were assessed based on five criteria. The details and findings of this assessment are outlined in Appendix 1.

The new circuit would be created by linking circuits north and south of Maynooth 220 kV station. The northern section between Woodland and Maynooth would be achieved by using the existing Gorman – Maynooth 220 kV circuit and the southern section would be achieved by using Dunstown – Maynooth 2 220 kV circuit.

- The existing Gorman - Maynooth 220 kV overhead line circuit will be modified to incorporate a "turn in" to Woodland 400 kV station. The "turn in" is marked in figure 3 by a blue oval. This will create two new circuits into Woodland station, namely a Gorman – Woodland 220 kV circuit and a circuit connecting Maynooth and Woodland (that will be used for up-voltage option). It should be noted that the technology used to create the connection into Woodland station will be determined in Step 3 and the any required routing will be carried out in Step 4.

- The newly created circuit connecting Maynooth and Woodland would be linked together with the existing Dunstown – Maynooth 2 220 kV circuit in the vicinity of Maynooth station. The circuits would then be modified to enable operation at 400 kV. The exact order of how this work will be achieved will be further investigated in Step 3 if this option remains.

7.1.3 Technical Performance

7.1.3.1 Thermal overload

In comparison to the alternative options, the up-voltage option performs very well in terms of remaining thermal overloads that are required to be resolved to fulfil a fully compliant solution with the Transmission System Security and Planning Standards (TSSPS). Just one additional uprate is required, the uprating of Bracklone – Portlaoise 110 kV circuit. This option is considered to have a low impact due to the small quantity of remaining thermal overloads after the up-voltage option have been implemented (**Cream**).

7.1.3.2 Phase angle

This option will reduce the difference in voltage phase angle to 20 degrees for the same event as described in the criteria. The result of this, is that the voltage phase angle does improve significantly relative to the other options and is as such considered to retain a low to moderate risk in relation to acceptable phase angles (**Green**).

7.1.3.3 Reactive support requirements

This option requires a dynamic reactive support device to fully meet the need, namely:

- Dynamic reactive support device in area of Inchicore station rated at approximately ±250 Mvar

The reactive support device is needed to help the conventional generators on the East coast to supply reactive power to prevent voltage collapse for an unplanned loss of any of the 400 kV overhead lines running from the west to the east of the country, in particular the Oldstreet – Woodland 400 kV line.

In addition, as Ireland is currently experiencing an increased interest in connection of more large scale demand on the East coast, the options were assessed based on their ability to accommodate more demand on the East coast. For this option to achieve the target described in the technical performance criteria in section 3.2.1 a suite of dynamic reactive support devices are required in addition to the above.

- Series capacitor installed on the Moneypoint – Oldstreet 400 kV overhead line

- Dynamic reactive support device in area of Dunstown station rated at approximately ±250 Mvar
- Dynamic reactive support device in area of Maynooth station rated at approximately ±250 Mvar

The series capacitor is required to prevent voltage collapse for the loss of the Coolnabacky – Moneypoint 400 kV line. Two reactive support devices are needed to help the conventional generators on the East coast to supply reactive power to prevent voltage collapse for an unplanned loss of the 400 kV overhead lines. Appendix 3 provides detail of the analysis done to identify reactive support requirements for this option. This option is considered to have a moderate performance based on the need for reactive support required (**Dark Green**).

7.1.3.4 Short Circuit Analysis

This option performs well in terms of reducing the short circuit currents at Maynooth station. The option will remove two existing 220 kV circuits currently connecting into Maynooth. Short circuit levels are immaterially increased at Woodland and Dunstown stations where the new circuit is connected. The results of the short circuit analysis can be found in Appendix 4. This option is considered to have a low to moderate performance in terms short circuit levels (**Green**).

7.1.3.5 Reinforcements to cater for maintenance conditions

This option may require additional reinforcements to keep the network within standards following a subsequent loss of plant and equipment whilst another is out for planned maintenance. Details of the criteria are found in section 3.2.

For the purpose of this assessment in Step 2, we have assessed the number of indicated violations of thermal capacity. A summary of the potential reinforcements are listed in table 2 and the full results of the analysis are shown in Appendix 2. This option is considered to have a moderate performance in terms of possible future reinforcements (**Dark Green**).

	Potential reinforcements areas following a subsequent loss of plant whilst another is out for maintenance
1	Coolnabacky – Portlaoise 110 kV
2	Cashla – Prospect 220 kV
3	Killonan - Shannonbridge 220kV OHL
4	Bracklone – Newbridge 110 kV
5	Maynooth - Shannonbridge 220kV OHL
6	Cashla – Flagford 220 kV
7	Agannygal – Shannonbridge 110 kV
8	Maynooth – Woodland 220 kV

9	Killoternan – Waterford 110 kV
10	Cullenagh – Waterford 110 kV

Table 2 *Potential reinforcements following a subsequent loss of plant whilst another is out for maintenance for up-voltage option*

7.1.3.6 Conclusion of technical performance

This option is considered to have moderate performance from a technical point of view when all technical aspects were considered and (**Dark Green)**.

Technical performance Up-voltage existing 220 kV circuits to 400 kV	Thermal overloads	Phase angle	Reactive support	Short circuit	Maintenance conditions	Combined Technical Performance

Table 3 *Summary of technical performance for up-voltage existing 220 kV to 400 kV*

7.1.4 Economic Performance

The estimated capital costs for the full solution for the up-voltage option is approximately €92m. This includes new bays, busbar extensions, line uprates or reactive support required. The estimated cost for the transmission system operator to develop the up-voltage option is approximately €15m. This option is considered to have moderate impact in terms of the cost (**Dark Green**).

7.1.5 Environmental

Having considered the potential environmental impacts for the up-voltage option it is concluded that this option will have moderate environmental impact (**Dark Green**) with impacts mainly related to the construction phase. This option uses existing corridors and maximises existing infrastructure as opposed to introducing the need to build new infrastructure in an area. Once operational, the up-voltage option would not be significantly different from the current baseline. The technology used will modify existing towers in existing corridors to towers of similar size and scale.

7.1.6 Deliverability

The technology proposed for the up-voltage option would enable the existing 220 kV towers to be modified and the 220 kV conductors replaced with 400 kV conductor to create a new Dunstown – Woodland 400 kV circuit. This would mean that the new towers will be of similar size and scale as the existing towers. Having assessed high level deliverability aspects for up-voltage existing 220 kV circuits to 400kV it is concluded

that this option would have low to moderate planning risks. The deliverability of this option will involve prolonged outages of existing circuits to allow the existing towers to be replaced with new towers. In Step 3 mitigation may be found for these outages. However, it is considered that this option will have a high to moderate impact in terms of potential circuit outages required. Overall, this option is considered to have a moderate impact on deliverability (**Dark Green**).

7.1.7 Socio-economic

A new asset in a socio-economic environment will, in general, always performance poorly relative to the re-use of the existing electricity grid. There is, however, a difference between above ground and underground options. This becomes evident in the scoring for settlements & communities; recreation & tourism landscape & visual criteria for the above ground option. The visual impact is significant and is interrelated to several other criteria

Overall, using the available information at this stage in the project, the up-voltage option perform better than a new circuit, this is largely due to the established nature of existing infrastructure in the socio economic environment. The replacement of existing infrastructure and up-voltage of an existing asset has the least impact in a socio-economic environment. From the analysis, it can be seen there is still an impact to settlements and communities who will facilitate the construction of and host the up-voltage. Having considered typical social impacts for the proposed upvoltage option it is concluded that it will have a neutral social impact, neither adverse nor beneficial. Therefore this option is considered to have moderate socio-economic impact (**Dark Green**).

7.1.8 Summary of option

Overall performance Up-voltage existing 220 kV circuits to 400 kV	Technical Performance	Economic Performance	Environmental	Deliverability	Socio-economic	Overall Performance

Table 4 *Summary of performance of all criteria for up-voltage option*

7.2 Dunstown – Woodland 400 kV OHL

7.2.1 Description of option

This option involves a suite of transmission network reinforcements centred on strengthening the network between existing Dunstown 400 kV station in County Kildare and Woodland 400 kV station in County Meath. These consist of:

- Construction of a new 400 kV overhead line linking Dunstown 400 kV station to Woodland 400 kV station.
- Uprating of the Bracklone – Portlaoise 110 kV overhead line
- Dynamic reactive support device in area of Inchicore station rated at approximately ±250 Mvar

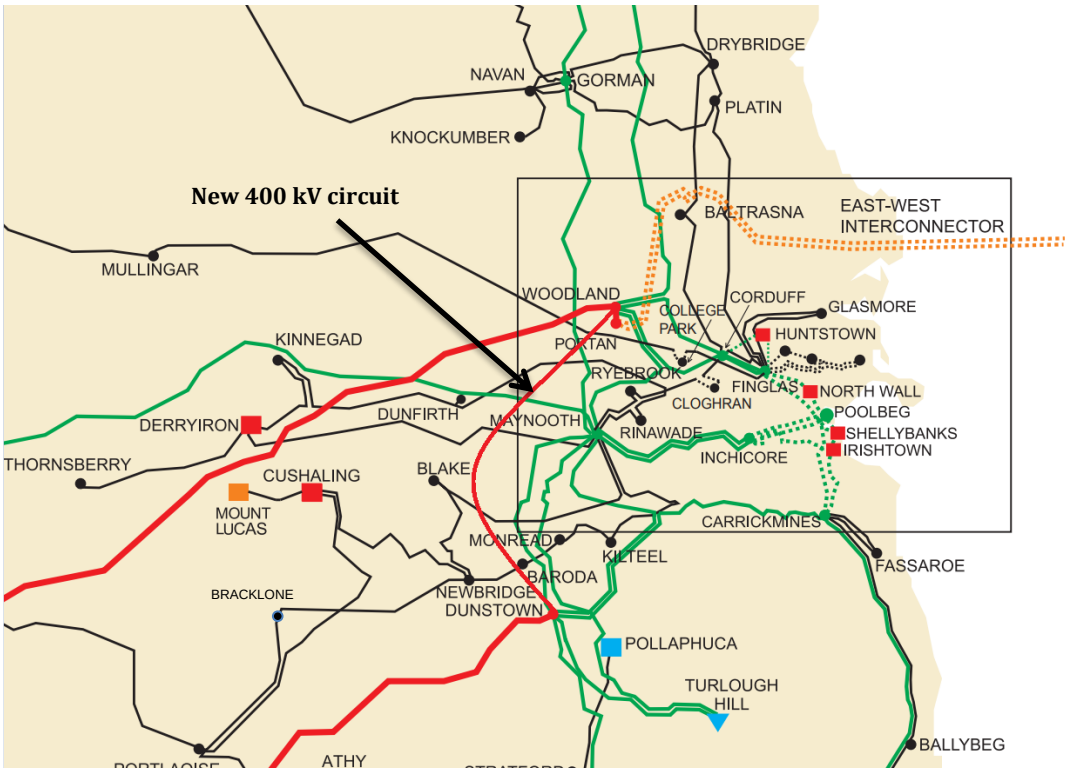


Figure 4 *Transmission system map showing a new 400 kV OHL (indicative) (the new 400 kV OHL between Dunstown and Woodland 400kV stations are shown in red, in a north southerly direction)*

7.2.2 Technical Performance

7.2.2.1 Thermal overloads

In comparison to the alternative options, the 400 kV OHL option performs very well in terms of remaining thermal overloads that are required to be resolved to fulfil a fully compliant solution with the Transmission System Security and Planning Standards (TSSPS). Just one additional uprate is required, the uprating of Bracklone – Portlaoise 110 kV circuit. This option is considered to have a low impact due to the small quantity of remaining thermal overloads after the 400 kV OHL option have been implemented (**Cream**).

7.2.2.2 Phase angle

This option will reduce the difference in voltage phase angle to 20 degrees for the same event as described in the criteria. The result of this is that the voltage phase angle does improve significantly relatively to the other options and is as such considered to retain a low to moderate risk in relation to acceptable phase angles (**Green**).

7.2.2.3 Reactive support requirements

This option requires a dynamic reactive support device to fully meet the need, namely:

- Dynamic reactive support device in area of Inchicore station rated at approximately ±250 Mvar

The reactive support device is needed to help the conventional generators on the East coast to supply reactive power to prevent voltage collapse for an unplanned loss of any of the 400 kV overhead lines running from the west to the east of the country, in particular the Oldstreet – Woodland line.

In addition, as Ireland is currently experiencing an increased interest in connection of more large scale demand on the East coast, the options were assessed based on their ability to accommodate more demand on the East coast. For this option to achieve the target described in the technical performance criteria in section 3.2.1, a suite of dynamic reactive support devices are required in addition to the above.

- Series capacitor installed on the Moneypoint – Oldstreet 400 kV overhead line
- Dynamic reactive support device in area of Dunstown station rated at approximately ±250 Mvar
- Dynamic reactive support device in area of Maynooth station rated at approximately ±250 Mvar

The series capacitor is required to prevent voltage collapse for the loss of the Coolnabacky – Moneypoint 400 kV line. Two reactive support devices are needed to help the conventional generators on the East coast to supply reactive power to prevent voltage collapse for an unplanned loss of the 400 kV overhead line. Appendix 3 provides detail of the analysis done to identify reactive support requirements for this option. This option is considered to have a moderate performance based on the need for reactive support required (**Dark Green**).

7.2.2.4 Short Circuit analysis

This option results in some increases in existing short circuit level due to the inclusion of an additional circuit. All increases in short circuit level remain within Grid Code levels, but represent a reduction in available headroom. Appendix 4 shows the result of the short circuit analysis. This option is considered to have a moderate performance in regards to short circuit levels (**Dark Green**).

7.2.2.5 Reinforcements to cater for maintenance conditions

This option may require additional reinforcements to keep the network within standards following a subsequent loss of plant and equipment whilst another is out for planned maintenance. Details of the criteria are found in section 3.2

For the purpose of this assessment in Step 2, we have assessed the number of indicated violations of thermal capacity. A summary of the potential reinforcements are listed in table 2 and the full results of the analysis are shown in Appendix 2. This option is considered to have a moderate performance in terms possible future reinforcements (**Dark Green**).

	Potential reinforcements following a subsequent loss of plant whilst another is out for maintenance
1	Coolnabacky – Portlaoise 110 kV
2	Cashla – Prospect 220 kV
3	Killonan - Shannonbridge 220kV OHL
4	Bracklone – Newbridge 110 kV
5	Maynooth - Shannonbridge 220kV OHL
6	Cashla – Flagford 220 kV
7	Maynooth – Woodland 220 kV
8	Agannygal – Shannonbridge 110 kV
9	Killoternan – Waterford 110 kV
10	Cullenagh – Waterford 110 kV

Table 5 *Potential reinforcements following a subsequent loss of plant whilst another is out for maintenance for 400 kV OHL option*

7.2.2.6 Conclusion of technical performance

This option is considered to have moderate performance from a technical point of view when all technical aspects were considered and (**Dark Green)**.

Technical performance for 400 kV OHL option	Thermal overloads	Phase angle	Reactive support	Short circuit	Maintenance conditions	Combined Technical Performance

Table 6 *Summary of technical performance for 400 kV OHL option*

7.2.3 Economic Performance

The estimated capital costs for the full solution for a new 400 kV overhead line option is approximately €95m. This includes new bays, busbar extensions, line uprates or reactive support required. The estimated cost for the transmission system operator to develop the 400 kV overhead line option is approximately €20m.This option is considered to have a moderate impact in terms of the cost (**Dark Green**).

7.2.4 Environmental

Using the available information at this stage in the project, and having considered the potential environmental impacts for a new 400 kV overhead line circuit, it is concluded that this option could result in a high environmental impact (**Dark Blue**) in comparison to utilising an existing transmission corridor. The construction of any new transmission infrastructure will compare poorly against other options using existing infrastructure.

7.2.5 Deliverability

Having assessed high level deliverability aspects for a new 400 kV overhead line circuit it is concluded that this option could potentially be associated with high planning risks. It is considered that this option will have a low to moderate impact in terms of potential outages required as it is mostly a new build with only outages required for energisation. Given the nature of the project the planning risks are considered to more difficult to mitigate and more dominant in delivering the project. Therefore, this option is considered to have an overall high to moderate impact on deliverability (**Blue**).

7.2.6 Socio-economic

A new asset in a socio-economic environment will, in general, always perform least favourably relative to other options which may use existing infrastructure. There is, however, a difference between above ground and underground options. This becomes evident in the evaluation regarding settlements & communities; recreation & tourism

landscape & visual criteria for the above ground options. The visual impact is significant and is interrelated to several other criteria.

Overall, using the available information at this stage in the project, this option performs least favourably against socio-economic aspects in comparison to the other available alternative options. The performance of the OHL option is least favourable largely as a result of the visual impact of OHL infrastructure which can be difficult to mitigate, particularly in a socio-economic environment. Therefore this option is considered to have high socio-economic impact (**Dark Blue**).

7.2.7 Summary of option

Overall performance of new 400 kV OHL circuit	Technical Performance	Economic Performance	Environmental	Deliverability	Socio-economic	Overall Performance

Table 7 *Summary of performance of all criteria for 400 kV OHL option*

7.3 Dunstown – Woodland 220 kV OHL circuit

7.3.1 Description of option

This option involves a suite of transmission network reinforcements centred on strengthening the network between existing Dunstown 400 kV station in County Kildare and Woodland 400 kV station in County Meath. These consist of:

- Construction of a new 220 kV overhead line linking Dunstown 400 kV station to Woodland 400 kV station.
- Uprating of the Bracklone – Portlaoise 110 kV overhead line
- Uprating of the Cashla – Prospect 220 kV overhead line
- Dynamic reactive support device in area of Inchicore station rated at approximately ±250 Mvar

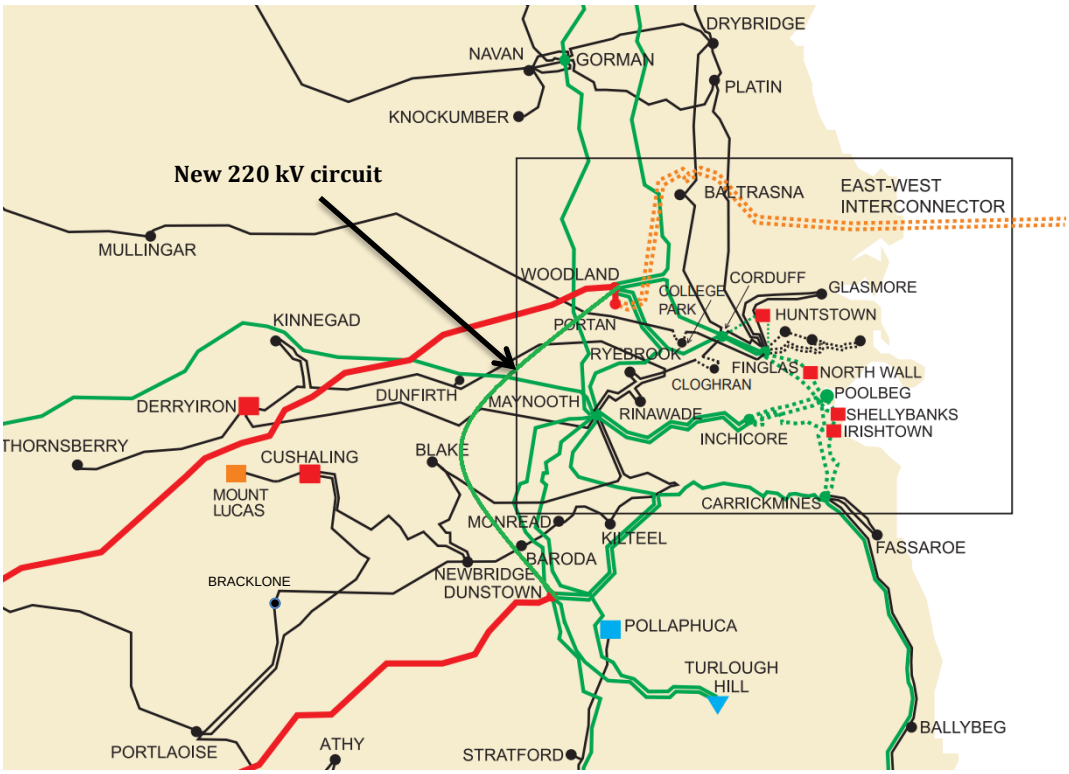


Figure 5 *Transmission system map showing a new 220 kV OHL (indicative) (the 220kV OHL between Dunstown and Woodland 400kV stations are shown as a green bow, in a north southerly direction)*

7.3.2 Technical Performance

7.3.2.1 Thermal overloads

In comparison to the alternative options the 220 kV OHL option performs poorly in terms of remaining thermal overloads that are required to be resolved to fulfil a fully compliant solution with the Transmission System Security and Planning Standards (TSSPS). Two additional uprates are required, the uprating of Bracklone – Portlaoise 110 kV circuit and Cashla – Prospect 220 kV. This option is considered to have a high to moderate impact on remaining overloads after the 220 kV OHL option have been implemented (**Blue**).

7.3.2.2 Phase angle

This option will reduce the difference in voltage phase angle to 35 degrees for the same event as described in the criteria. The result of this is that the voltage phase angle does not improve much relatively to the other options and is as such considered to retain a high risk in relation to acceptable phase angles (**Dark Blue**).

7.3.2.3 Reactive support requirements

This option requires a dynamic reactive support device to fully meet the need, namely:

- Dynamic reactive support device in area of Inchicore station rated at approximately ±250 Mvar

The reactive support device is needed to help the conventional generators on the East coast to supply reactive power to prevent voltage collapse for an unplanned loss of any of the 400 kV overhead lines running from the west to the east of the country, in particular the Oldstreet – Woodland line.

In addition, as Ireland is currently experiencing an increased interest in connection of more large scale demand on the East coast, the options were assessed based on their ability to accommodate more demand on the East coast. For this option to achieve the target described in the technical performance criteria in section 3.2.1, a suite of dynamic reactive support devices are required in addition to the above.

- Series capacitor installed on the Moneypoint – Oldstreet 400 kV overhead line
- Dynamic reactive support device in area of Dunstown station rated at approximately ±250 Mvar
- Dynamic reactive support device in area of Maynooth station rated at approximately ±250 Mvar

- Dynamic reactive support device in area of Belcamp station rated at approximately ±250 Mvar
- Dynamic reactive support device in area of Carrickmines station rated at approximately ±250 Mvar

The series capacitor is required to prevent voltage collapse for the loss of the Coolnabacky – Moneypoint 400 kV line. Four reactive support devices are needed to help the conventional generators on the East coast to supply reactive power to prevent voltage collapse for an unplanned loss of the 400 kV overhead line. Appendix 3 provides detail of the analysis done to identify reactive support requirements for this option. This option is considered to have a high requirement in regards to reactive support required (**Dark Blue**).

7.3.2.4 Short Circuit Analysis

This option results in some increases in existing short circuit levels due to the inclusion of an additional circuit. All increases in short circuit level remain within acceptable Grid Code levels, but represent a reduction in available headroom. Appendix 4 shows the result of the short circuit analysis. This option is considered to have a moderate performance in regards to short circuit levels (**Dark Green**).

7.3.2.5 Reinforcements to cater for maintenance conditions

This option may require additional reinforcements to keep the network within standards following a subsequent loss of plant and equipment whilst another is out for planned maintenance. Details of the criteria are found in section 3.2

For the purpose of this assessment in Step 2, we have assessed the number of indicated violations of thermal capacity. A summary of the potential reinforcements are listed in table 8 and the full results of the analysis are shown in Appendix 2. This option is considered to have a high to moderate performance in terms possible future reinforcements (**Blue**).

	Potential reinforcements following a subsequent loss of plant whilst another is out for maintenance
1	Coolnabacky – Portlaoise 110 kV
3	Killonan - Shannonbridge 220kV OHL
4	Bracklone – Newbridge 110 kV
5	Maynooth - Shannonbridge 220kV OHL
6	Cashla – Flagford 220 kV
7	Agannygal – Shannonbridge 110 kV
8	Athlone – Lanesboro 110 kV
9	Maynooth – Woodland 220 kV
10	Third 400/220 kV transformer in Dunstown

11	Killoternan – Waterford 110 kV
12	Cullenagh – Waterford 110 kV

Table 8 *Potential reinforcements following a subsequent loss of plant whilst another is out for maintenance for the 220 kV OHL option*

7.3.2.6 Conclusion of technical performance

This option is considered to have less favourable performance from a technical point of view when all technical aspects were considered. It is considered that the thermal overloads, voltage phase angles and reactive support requirement are the more dominant concerns from a technical perspective and as such the combined technical performance leaned to the low performance **(Dark Blue)**

Technical performance for 220 kV OHL option	Thermal overloads	Phase angle	Reactive support	Short circuit	Maintenance conditions	Combined Technical Performance

Table 9 *Summary of the* technical performance for *220 kV OHL option*

7.3.3 Economic Performance

The estimated capital costs for the full solution for a new 220 kV overhead line option is approximately €86m. This includes new bays, busbar extensions, line uprates or reactive support required. The estimated cost for the transmission system operator to develop the 220 kV overhead line option is approximately €20m.This option is considered to have moderate impact in terms of the cost (**Dark Green**).

7.3.4 Environmental

Using the available information at this stage in the project, in terms of potential environmental impacts, the construction and operation of a 400 kV or 220 kV overhead line would be similar. Therefore, having considered the potential environmental impacts for a new 400 kV overhead line circuit, it is concluded that similar impacts would be associated with a new 220 kV option. This could result in a high environmental impact (**Dark Blue**) in comparison to utilising an existing transmission corridor. The construction of any new transmission infrastructure will compare poorly against other options using existing infrastructure.

7.3.5 Deliverability

Having assessed high level deliverability aspects for a new 220 kV overhead line circuit it is concluded that this option could potentially be associated with high planning risks. It is considered that this option will have a low to moderate impact in terms of potential outages required as it is mostly a new build with only outages required for energisation. Given the nature of the project the planning risks are considered to more difficult to mitigate and more dominant in delivering the project. Therefore, this option is considered to have an overall high to moderate impact on deliverability (**Blue**).

7.3.6 Socio-economic

A new asset in a socio-economic environment will, in general, always perform least favourably relative to other options which may use existing infrastructure. There is, however, a difference between above ground and underground options. This becomes evident in the evaluation regarding settlements & communities; recreation & tourism landscape & visual criteria for the above ground options. The visual impact is significant and is interrelated to several other criteria.

Overall, using the available information at this stage in the project, this option performs least favourably against socio-economic aspects in comparison to the other available alternative options. The performance of the OHL option is least favourable largely as a result of the visual impact of OHL infrastructure which can be difficult to mitigate, particularly in a socio-economic environment. . Therefore this option is considered to have high socio-economic impact (**Dark Blue**)

7.3.7 Summary of option

Overall performance of new 220 kV OHL circuit	Technical Performance	Economic Performance	Environmental	Deliverability	Socio-economic	Overall Performance

Table 10 *Summary of performance of all criteria for the 220 kV OHL*

7.4 Dunstown – Woodland 220 kV UGC circuit

7.4.1 Description of option

This option involves a suite of transmission network reinforcements centred on strengthening the network between existing Dunstown 400 kV station in County Kildare and Woodland 400 kV station in County Meath. These consist of:

- Construction of a new 220 kV underground cable linking Dunstown 400 kV station to Woodland 400 kV station.
- Uprating of the Bracklone – Portlaoise 110 kV overhead line
- Uprating of the Cashla – Prospect 220 kV overhead line
- Uprating of the Killonan – Shannonbridge 220 kV overhead line
- Woodland 220 kV station would be required to be operated “split” in order to prevent thermal overloading of the new 220 kV cable for an unplanned loss of a circuit
- Dynamic reactive support device in area of Inchicore station rated at approximately ±250 Mvar

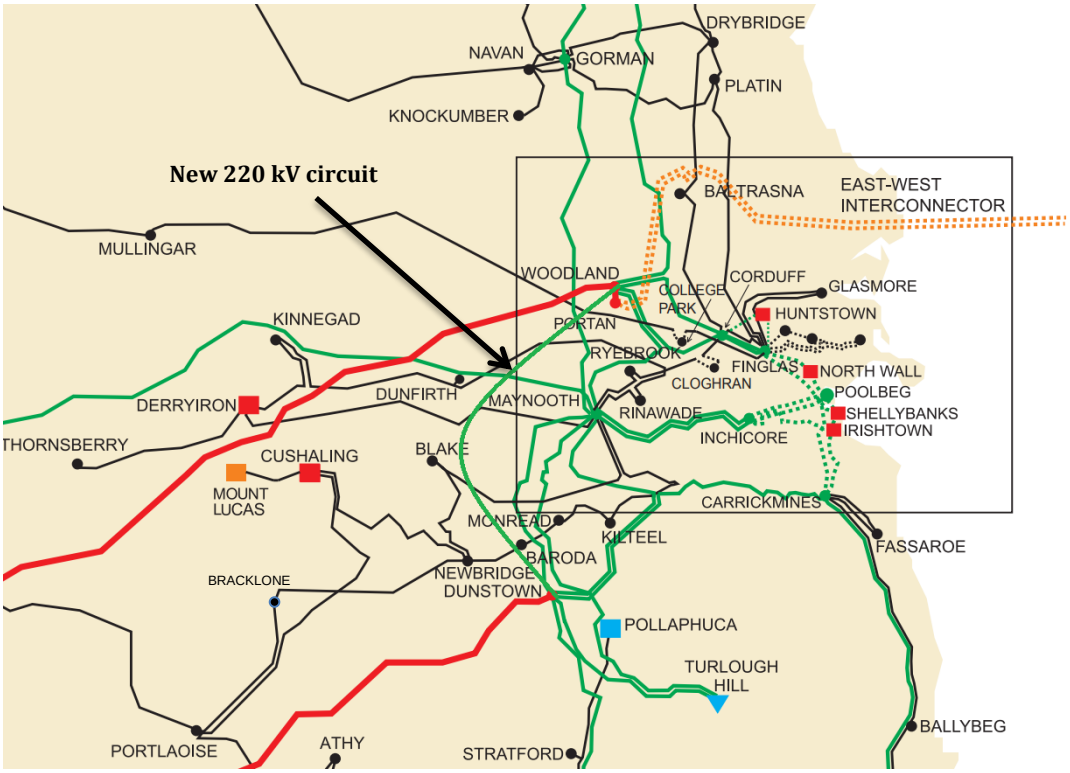


Figure 6 *Transmission system map showing a new 220 kV UGC (indicative) (the 220kV UGC between Dunstown and Woodland 400kV stations are shown as a green bow, in a north southerly direction)*

7.4.2 Technical Performance

7.4.2.1 Thermal overloads

In comparison to the alternative options, the 220 kV UGC option performs poorly in terms of remaining thermal overloads that are required to be resolved to fulfil a fully compliant solution with the Transmission System Security and Planning Standards (TSSPS). Three additional uprates are required, the uprating of Bracklone – Portlaoise 110 kV circuit, Cashla – Prospect 220 kV and the uprate of Killonan – Shannonbridge 220 kV. The two latter circuits are very long and are 220 kV circuits. This option is considered to have a high impact on remaining overloads after the 220 kV UGC option have been implemented (**Dark Blue**).

7.4.2.2 Phase angle

This option will reduce the difference in voltage phase angle to 32 degrees for the same event as described in the criteria. This option results in that the voltage phase angle do not improve much relatively to the other options and is as such considered to retain a high risk in relation to acceptable phase angles (**Dark Blue**)

7.4.2.3 Reactive support requirements

This option requires reactive a support device to fully meet the need, namely:

- Dynamic reactive support device in area of Inchicore station rated at approximately ±250 Mvar

The reactive support device is needed to help the conventional generators on the East coast to supply reactive power to prevent voltage collapse for an unplanned loss of any of the 400 kV overhead lines running from the west to the east of the country, in particular the Oldstreet – Woodland line.

In addition, as Ireland is currently experiencing an increased interest in connection of more large scale demand on the East coast, the options were assessed based on their ability to accommodate more demand on the East coast. For this option to achieve the target described in the technical performance criteria in section 3.2.1, a suite of dynamic reactive support devices are required in addition to the above.

- Series capacitor installed on the Moneypoint – Oldstreet 400 kV overhead line
- Dynamic reactive support device in area of Maynooth station rated at approximately ±250 Mvar
- Dynamic reactive support device in area of Belcamp station rated at approximately ±250 Mvar
- Dynamic reactive support device in area of Carrickmines station rated at approximately ±250 Mvar

The series capacitor is required to prevent voltage collapse for the loss of the Coolnabacky – Moneypoint 400 kV line. Three reactive support devices are needed to help the conventional generators on the East coast to supply reactive power to prevent voltage collapse for an unplanned loss of the 400 kV overhead line. Appendix 3 provides detail of the analysis done to identify reactive support requirements for this option. This option is considered to have a high to moderate requirement in regards to reactive support required (**Blue**).

7.4.2.4 Short Circuit Analysis

This option results in some increases in existing short circuit levels due to the inclusion of an additional circuit. All increases in short circuit level remain within acceptable Grid Code levels, but represent a reduction in available headroom. Appendix 4 shows the result of the short circuit analysis. This option is considered to have a moderate performance in regards to short circuit levels (**Dark Green**).

7.4.2.5 Reinforcements to cater for maintenance conditions

This option may require additional reinforcements to keep the network within standards following a subsequent loss of plant and equipment whilst another is out for planned maintenance. Details of the criteria are found in section 3.2

For the purpose of this assessment in Step 2, we have assessed the number of indicated violations of thermal capacity. A summary of the potential reinforcements are listed in table 11 and the full results of the analysis are shown in Appendix 2. This option is considered to have a moderate performance in terms possible future reinforcements (**Dark Green**).

	Potential reinforcements following a subsequent loss of plant whilst another is out for maintenance
1	Coolnabacky – Portlaoise 110 kV
2	Bracklone – Newbridge 110 kV
3	Maynooth - Shannonbridge 220kV OHL
4	Cashla – Flagford 220 kV
5	Agannygal – Shannonbridge 110 kV
6	Maynooth – Woodland 220 kV
7	Third 400/220 kV transformer in Dunstown
8	Killoternan – Waterford 110 kV
9	Cullenagh – Waterford 110 kV
10	Butlerstown – Cullenagh 110 kV

Table 11 *Potential reinforcements following a subsequent loss of plant whilst another is out for maintenance for the 220 kV UGC option*

7.4.2.6 Conclusion of technical performance

This option is considered to have less favourable performance from a technical point of view when all technical aspects were considered. It is considered that the thermal overloads, voltage phase angles and reactive support requirement are the more dominant concerns from a technical perspective and as such the combined technical performance leaned to the low performance (**Dark Blue**).

Technical performance for 220 kV UGC option	Thermal overloads	Phase angle	Reactive support	Short circuit	Maintenance conditions	Combined Technical Performance

Table 12 *Summary of technical performance for 220 kV UGC option*

7.4.3 Economic Performance

The estimated capital costs for the full solution for a new 220 kV underground cable option is approximately €173m. This includes new bays, busbar extensions, line uprates or reactive support required. The estimated cost for the transmission system operator to

develop the 220 kV underground cable option is approximately €13m.This option is considered to have high impact in terms of the cost (**Dark Blue**).

7.4.4 Environmental

Using the available information at this stage in the project, and having considered the potential environmental impacts that may be associated with the construction and operation of a new 220kV underground circuit, it is concluded that this option may result in a high to moderate environmental impacts (**Blue**) in comparison to utilising an existing transmission corridor. The construction of any new transmission infrastructure will compare poorly against other options using existing infrastructure. The installation of an underground cable is not without environmental impacts, the determination of the significance of which would require more detailed assessment as the options move through the various steps in the framework for Grid Development.

7.4.5 Deliverability

Having assessed high level deliverability aspects for a new 220 kV underground circuit it is concluded that this option would not be associated with significant planning risks as cables are exempt from planning. However, some other elements of the option still require planning, such as reactive support requirements, so the option will still have moderate planning risks associated. It is considered that this option will have a low to moderate impact in terms of potential circuit outages required as it is mostly a new build with only outages required for energisation. In addition, it is assumed that the 220 kV underground cable will be laid along existing roads and during construction this will most likely have an impact on traffic and should be recognised. Therefore, this option is considered to have an overall moderate impact on deliverability (**Dark Green**).

7.4.6 Socio-economic

A new asset in a socio-economic environment will, in general, always perform least favourably relative to other options which may use existing infrastructure. There is, however, a difference between above ground and underground options. This becomes evident in the evaluation regarding settlements & communities; recreation & tourism landscape & visual criteria for the above ground options.

Overall, this option performs moderately against socio-economic aspects. The introduction of new infrastructure onto the socio-economic environment will create impacts, however this is mitigated to a certain extent as this option is underground. However, there is still some socio-economic impact. Therefore this option is considered to have moderate socio-economic impact (**Dark Green**).

7.4.7 Summary of option

Overall performance of new 220 kV UGC circuit	Technical Performance	Economic Performance	Environmental	Deliverability	Socio-economic	Overall Performance

Table 13 *Summary of performance of all criteria for the 220 kV UGC option*

7.5 Dunstown – Woodland 400 kV UGC circuit

7.5.1 Description of option

This option involves a suite of transmission network reinforcements centred on strengthening the network between existing Dunstown 400 kV station in County Kildare and Woodland 400 kV station in County Meath. These consist of:

- Construction of a new HVAC 400 kV underground cable linking Dunstown 400 kV station to Woodland 400 kV station.
- Uprating of the Bracklone – Portlaoise 110 kV overhead line
- Dynamic reactive support device in area of Inchicore station rated at approximately ±250 Mvar

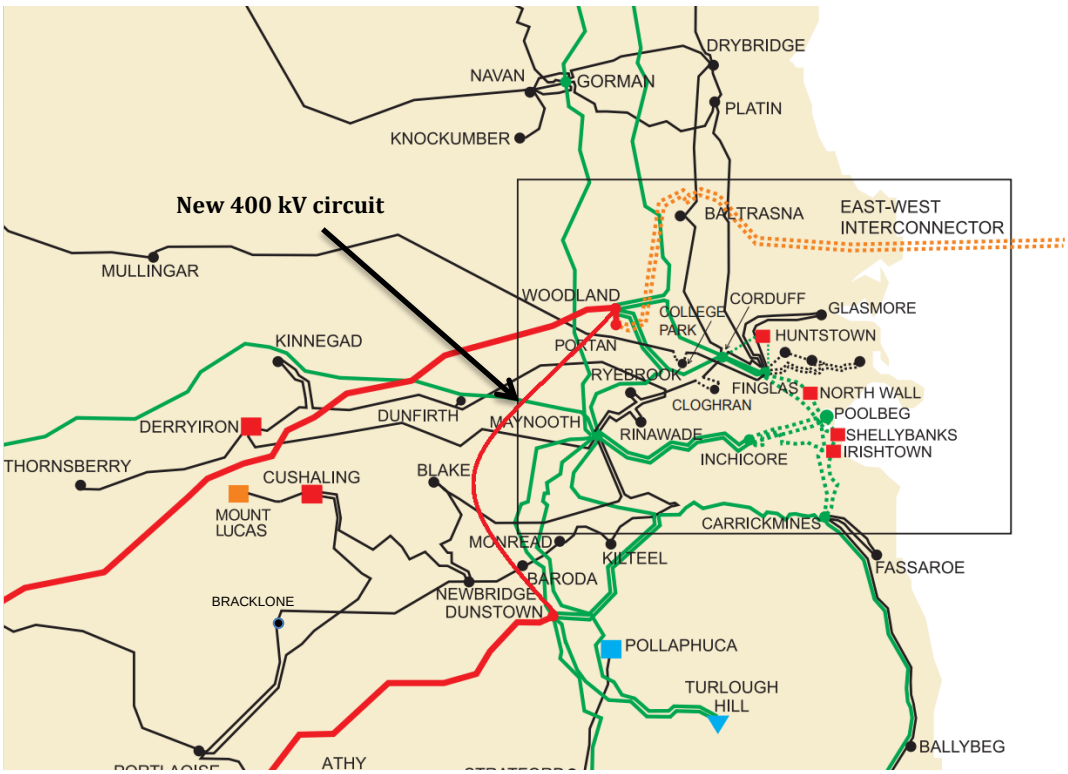


Figure 7 *Transmission system map showing a new 400 kV UGC (indicative) (the 400kV UGC between Dunstown and Woodland 400kV stations are shown as a red bow, in a north southerly direction)*

7.5.2 Technical Performance

7.5.2.1 Thermal overloads

In comparison to the alternative options the 400 kV UGC option performs very well in terms of remaining thermal overloads that are required to be resolved to fulfil a fully compliant solution with the Transmission System Security and Planning Standards (TSSPS). Just one additional uprate is required, the uprating of Bracklone – Portlaoise 110 kV circuit. This option is considered to have a low impact on remaining overloads after the 400 kV UGC option have been implemented (**Cream**).

7.5.2.2 Phase angle

This option will reduce the difference in voltage phase angle to 17 degrees for the same event as described in the criteria. The result of this is that the voltage phase angle does improve significantly relative to the other options and is as such considered to retain a low risk in relation to acceptable phase angles (**Cream**).

7.5.2.3 Reactive Compensation Requirements

This option requires a dynamic reactive support device to fully meet the need, namely:

- Dynamic reactive support device in area of Inchicore station rated at approximately ±250 Mvar

The reactive support device is needed to help the conventional generators on the East coast to supply reactive power to prevent voltage collapse for an unplanned loss of any of the 400 kV overhead lines running from the west to the east of the country, in particular the Oldstreet – Woodland line.

In addition, as Ireland is currently experiencing an increased interest in connection of more large scale demand on the East coast, the options were assessed based on their ability to accommodate more demand on the East coast. For this option to achieve the target described in the technical performance criteria in section 3.2.1, another compensation device is required in addition to the above.

- Series capacitor installed on the Moneypoint – Oldstreet 400 kV overhead line

The series capacitor is required to prevent voltage collapse for the loss of the Coolnabacky – Moneypoint 400 kV line. Appendix 3 provides detail of the analysis done to identify reactive support requirements for this option. This option is considered to have a low requirement in regards to reactive support required (**Cream**).

7.5.2.4 Short Circuit Analysis

This option results in some increases in existing short circuit levels due to the inclusion of an additional circuit. All increases in short circuit level remain within acceptable Grid Code levels, but represent a reduction in available headroom. Appendix 4 shows the result of the short circuit analysis. This option is considered to have a moderate performance in regards to short circuit levels (**Dark Green**).

7.5.2.5 Reinforcements to cater for maintenance conditions

This option may require additional reinforcements to keep the network within standards following a subsequent loss of plant and equipment whilst another is out for planned maintenance. Details of the criteria are found in section 3.2

For the purpose of this assessment in Step 2, we have assessed the number of indicated violations of thermal capacity. A summary of the potential reinforcements are listed in table 14 and the full results of the analysis are shown in Appendix 2. This option is considered to have a moderate performance in terms possible future reinforcements (**Dark Green**).

	Potential reinforcements following a subsequent loss of plant whilst another is out for maintenance
1	Coolnabacky – Portlaoise 110 kV
2	Cashla – Prospect 110 kV
3	Bracklone – Newbridge 110 kV
4	Killonan – Shannonbridge 220 kV
5	Maynooth - Shannonbridge 220kV OHL
6	Cashla – Flagford 220 kV
7	Agannygal – Shannonbridge 110 kV
8	Maynooth – Woodland 220 kV
9	Killoternan – Waterford 110 kV
10	Cullenagh – Waterford 110 kV
11	Butlerstown – Cullenagh 110 kV

Table 14 *Potential reinforcements following a subsequent loss of plant whilst another is out for maintenance for the 400 kV UGC option*

7.5.2.6 Conclusion of technical performance

This option is considered to have good performance from a technical point of view (**Green**) when all technical aspects were considered.

Technical performance for 400 kV UGC option	Thermal overloads	Phase angle	Reactive support	Short circuit	Maintenance conditions	Combined Technical Performance

Table 15 *Summary of technical performance for 400 kV UGC option*

7.5.3 Economic Performance

The estimated capital costs for the full solution for a new 400 kV underground option is approximately €160m. This includes any new bays, busbar extensions, line uprates or reactive support required. The estimated cost for the transmission system operator to develop the 400 kV underground option is approximately €13m.This option is considered to have high impact in terms of the cost (**Dark Blue**).

7.5.4 Environmental

In terms of potential environmental impacts, the construction and operation of a 400 kV or 220 kV underground circuit would be similar. Therefore, having considered the potential environmental impacts for a new 220 kV underground circuit, it is concluded that this option may result in a high to moderate environmental impacts (**Blue**) in comparison to utilising an existing transmission corridor. The installation of an underground cable is not without environmental impacts, the determination of the significance of which would require more detailed assessment as the options move through the various steps in the framework for Grid Development.

7.5.5 Deliverability

Having assessed high level deliverability aspects for a new 400 kV underground circuit it is concluded that this option would not be associated with planning risks as cables are exempt from planning. However, some other elements of the option still require planning, such as reactive support requirements, so the option will still have moderate planning risks associated. It is considered that this option will have a low to moderate impact in terms of potential outages required as it is mostly a new build with only outages required for energisation. In addition, it should be recognised that it may not be possible to lay a 400 kV underground cable along existing roads due to the cable trench width required . If this is the case, the 400 kV underground cable option may have to be laid across open fields. During construction this will most likely have an impact on various issues that will be considered in Step 3 but the possibility of impact on deliverability should be recognised. Therefore, this option is considered to have an overall moderate impact on deliverability (**Dark Green**).

7.5.6 Socio-economic

A new asset in a socio-economic environment will, in general, always perform least favourably relative to other options which may use existing infrastructure. There is, however, a difference between above ground and underground options. This becomes

evident in the evaluation regarding settlements & communities; recreation & tourism landscape & visual criteria for the above ground options.

Overall, this option performs moderately against socio-economic aspects. The introduction of new infrastructure onto the socio-economic environment will create impacts, however this is mitigated to a certain extent as this option is underground. However, there is still some socio-economic impact. Therefore this option is considered to have moderate socio-economic impact (**Dark Green**).

7.5.7 Summary of option

Overall performance of new 400 kV UGC circuit	Technical Performance	Economic Performance	Environmental	Deliverability	Socio-economic	Overall Performance

Table 16 *Summary of performance of all criteria for the 400 kV UGC*

7.6 Summary of the performance of options

7.6.1 Technical Performance

The technical performance of each option was assessed to achieve Transmission System Security and Planning Standards (TSSPS) compliant solutions. In addition, certain aspects were looked at in detail to distinguish between the options such as the difference in thermal overloads, improvements in phase angles, difference in reactive support requirements, changes in short circuit levels and how the options performed under maintenance conditions. It should be noted that the relative performance between the options may change in Step 3 when further analysis is carried out.

Estimated Technical performance for options	Up-voltage option	400 kV OHL	220 kV OHL	220 kV UGC	400 kV UGC

Table 17 *Summary of technical performance for all options*

7.6.2 Economic Performance

The economic performance of the options is based on capital costs for each option. Each option is fully assessed to achieve a Transmission System Security and Planning Standards (TSSPS) compliant solution. The capital costs for the five options range between €86m – €173m. Each option is also assessed on estimated cost for the

transmission system operator to develop. These costs range between €13-20m for the five options.

Estimated economic performance for options	Up-voltage option	400 kV OHL	220 kV OHL	220 kV UGC	400 kV UGC

Table 18 *Summary of economic performance for all options*

7.6.3 Environmental

The options were assessed, on a high level, for potential environmental impacts. The construction of any new transmission infrastructure will compare poorly against other options using existing infrastructure. It is also recognised that the installation of an underground option is not without environmental impacts. An underground option will have a slightly better environmental performance in comparison with an above ground solution on a high level general comparison. Exceptions may be found in further, more detailed, investigations of routes which happen in Step 4.

Estimated environmental aspects	Up-voltage option	400 kV OHL	220 kV OHL	220 kV UGC	400 kV UGC

Table 19 *Summary of environmental aspects for all options*

7.6.4 Deliverability

The deliverability aspects in regards to timelines, planning risks and outages were assessed on a high level for the options. All the options involving new infrastructure were associated with low outages as is assumed that they will be constructed off-line with minimal outages required to connect to the transmission system. The up-voltage option is very dependent on outages as it requires existing circuits to be out of service for a prolonged period of time to facilitate the up-voltage work. All options could have a range of different planning risks and other aspects associated with their technology and this was reflected in the assessment.

Estimated deliverability aspects	Up-voltage option	400 kV OHL	220 kV OHL	220 kV UGC	400 kV UGC

Table 20 *Summary of deliverability aspects for all options*

7.6.5 Socio-economic

A new asset in a socio-economic environment will, in general, always perform poorly relative to other options which may use existing infrastructure. There is also a difference between above ground and underground options.

Estimated socio-economic aspects	Up-voltage option	400 kV OHL	220 kV OHL	220 kV UGC	400 kV UGC

Table 21 *Summary of socio-economic performance for all options*

8 Conclusions

EirGrid follow a six step approach when we develop and implement the best performing solution option to any identified transmission network problem. The transmission network problem for Capital Project 966 was identified and described in previous Step 1 and was documented in the Need Report.

The need, in this case, involves a transmission network problem regarding the transfer of power across the existing 400 kV transmission network from west to east and the transfer of this power within the transmission network as it reaches the east coast. The issues encountered involve both capacity and voltage.

Capital Project 966 has now gone through Step 2 of the framework for grid development. Step 2 was carried out in two parts. Part A covered the aspects that were considered when the long list of options was created and the first refinement of this list. This is documented in Options Report Part A. The outcome of the second part of refinement of the list has been presented in this report, Options Report Part B (this document).

The outcome from the Part B in Step 2 is that four solution options will be brought forward for further analysis in Step 3. There are some common requirements for all options and they are listed last. The four options are:

1. Up-voltage option
    - Up-voltage some of the existing 220 kV circuits between existing Dunstown 400 kV station and Woodland 400 kV station. Using a new technology which would enable the existing 220 kV towers to be modified and the 220 kV conductors replaced with 400 kV conductor to create a

new Dunstown – Woodland 400 kV circuit. The circuits selected to achieve this are Gorman – Maynooth 220 kV circuit and the Dunstown – Maynooth 2 220 kV circuit.

2. 400 kV OHL option
    - Construction of a new 400 kV overhead line linking Dunstown 400 kV station to Woodland 400 kV station.
3. Underground cable (220 kV or 400 kV)
    - Construction of a new 220 kV or 400 kV underground cable linking Dunstown 400 kV station to Woodland 400 kV station.

    If a 220 kV cable is the best performing option then, the following additional reinforcements are required:

    - Uprating of the Cashla – Prospect 220 kV overhead line
    - Uprating of the Killonan – Shannonbridge 220 kV overhead line
    - Woodland 220 kV station would be required to be operated “split” in order to prevent thermal overloading of the new 220 kV cable for an unplanned loss of a circuit
4. Common requirements for all options:
    - Uprating of the Bracklone – Portlaoise 110 kV overhead line
    - Dynamic reactive support device in area of Inchicore station rated at approximately ±250 Mvar

Appendix 1 – Selection of existing 220 kV circuit to use for up-voltage option

This appendix provides a summary of the assessment of which of the existing 220 kV circuits between Dunstown and Woodland stations would be the best candidates to use for the up-voltage option. The new circuit would be created by linking circuits north and south of Maynooth 220 kV station. The circuits possible to use for the up-voltage option are:

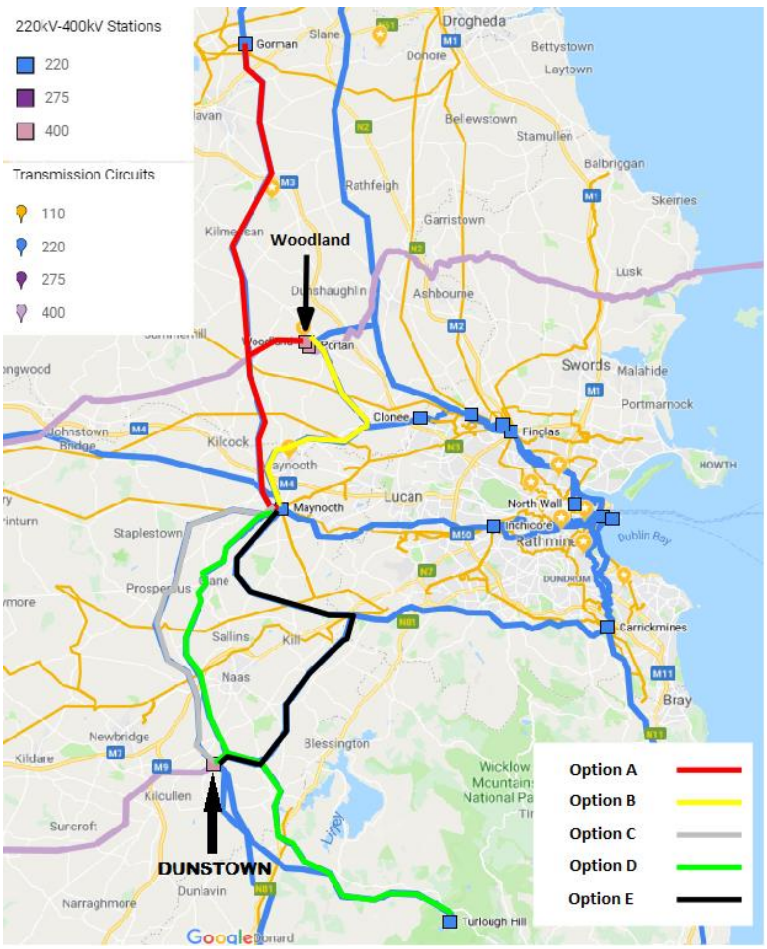
A. Gorman – Maynooth 220 kV (indicated with red colour in figure below)

B. Maynooth – Woodland 220 kV (indicated with yellow colour in figure below)

C. Dunstown – Maynooth 220 kV crt 2 (indicated with gry colour in figure below)

D. Maynooth – Turlough Hill 220 kV (indicated with green colour in figure below)

E. Dunstown – Maynooth 220 kV crt 1 (indicated with black colour in figure below)



All the existing 220 kV circuits between Dunstown and Maynooth were assessed based on five criteria. It is assumed that the Bracklone – Portlaoise 110 kV overhead line is uprated before the works involved in the up-voltage option can be carried out as this overload was common to all options in in the refined long list. This was previously identified in the report in section 7, Detailed evaluation of options.

This is a high level assessment to get an indication of potential differences between the circuits. In addition, more detailed analysis of the best preforming circuits will be carried out in Step 3 if this option remains. Some nuances in the technical, economic and deliverability criteria were added to make the comparison useful for this specific assessment. For the deliverability criteria we assessed the outage implications that each individual circuit will impose on the system during the required up-voltage works. We assumed each line option to be taken out of service in turn and subsequently applied an unplanned trip of another item of plant to get an indication of the severity impact on the system that this may cause. The implications for the system were then assessed on a high level by the amount of re-dispatch required to resolve the issue. As this is a new technology we do not have any cost assumptions available. To make an assessment for the economic criteria it was decided to use the cost of building a new circuit along the existing route.

Northern section between Maynooth and Woodland

In the northern section, there are two circuits which could be used to link the circuits north of Maynooth 220 kV station with circuits to the south. Each option is assessed against the five criteria and a justification and reasoning given for the assessment.

Existing 220 kV circuits	Technical Performance	Economic Performance	Environmental	Deliverability	Socio-economic	Combined Performance
Gorman-Maynooth 220 kV						
Maynooth Woodland 220 kV						

Table 22 *Overall comparison of up-voltage options in northern section using five criteria*

Technical performance and Deliverability aspects

The technical performance of the Gorman – Maynooth 220 kV circuit option does not cause any thermal overloads for an unplanned loss of any item of plant during the assumed construction phase. This is in contrast to Maynooth – Woodland 220 kV circuit, which would require significant generation constraint to allow the Maynooth – Woodland

220 kV circuit to be switched out for a longer period of time to implement the up-voltage work. The most influencing factor is that the Maynooth – Woodland 220 kV circuit share double circuit towers with Woodland – Clonee 220 kV for approximately 9 km and Maynooth – Shannonbridge 220 kV for approximately 1 km. The sharing of towers means that both circuits have to be taken out at the same time. This has an impact on the security and capacity of the transmission network in Dublin, which is reflected in the technical and deliverability criteria. The two options, respectively, have a low to moderate (**Green**) impact and a high impact (**Dark Blue**).

Economic Performance

A high level assessment of the estimated capital cost for the circuits in the northern section concluded that both circuits have a low to moderate cost impact (**Green**). The estimates are in the range €19 – 22m.

Environmental aspects

Having considered the potential environmental impacts for the up-voltage of the circuits in the northern section, it is concluded that the Maynooth – Woodland 220 kV circuit may have a slightly lower impact than the Gorman – Woodland 220 kV circuit. Potential impacts take into account construction and the requirement for a section of new build infrastructure on the Gorman – Woodland 220 kV circuit gives this a performance of moderate environmental impact (**Dark Green**) while Maynooth – Woodland 220 kV circuit has a performance of low to moderate environmental impact (**Green**). Both alternatives perform similarly overall. The transmission lines traverse farmland in the main and do not cross areas of high environmental sensitivity such as European Sites etc.

Socio-economic

Having considered typical socio-economic impacts for the circuits in the northern section it is concluded both options perform similarly in terms of socio—economic aspects. While the Gorman – Woodland 220 kV circuit will require a section of new build infrastructure, the Maynooth – Woodland 220 kV circuit's proximity to Maynooth Town and its amenities created additional risk. Both options are considered to have moderate socio-economic impact (**Dark Green**).

Southern section between Dunstown and Maynooth

In the southern section, there are three existing circuits which could be used to link the circuits south of Maynooth 220 kV station with circuits to the north. Each option is assessed against the five criteria and a justification and reasoning given for the assessment.

Existing 220 kV circuits	Technical Performance	Economic Performance	Environmental	Deliverability	Socio-economic	Combined Performance
Dunstown – Maynooth 220 kV cct 1						
Dunstown – Maynooth 220 kV cct 2						
Maynooth – Turlough Hill 220 kV						

Table 23 *Overall comparison of up-voltage options in southern section using five criteria*

Technical performance and Deliverability

The technical performance of the Maynooth – Turlough Hill 220 kV circuit option does not cause any thermal overloads for an unplanned loss of any item of plant during the assumed construction phase. It should be noted that this is one of two lines feeding the pump storage plant Turlough Hill. This option is considered to have low to moderate technical and deliverability impact (**Green**).

The Dunstown – Maynooth 220 kV circuit 2 does also perform well as it does not cause any thermal overloads for an unplanned loss of any item of plant during the assumed construction phase. This option is considered to have low to moderate technical and deliverability impact (**Green**).

The Dunstown – Maynooth 220 kV circuit 1, would require significant generation constraint to allow the this 220 kV circuit to be switched out for a longer period of time to implement the up-voltage work. The most influencing factor is that the Dunstown – Maynooth 220 kV circuit 1 shares double circuit towers with Carrickmines – Dunstown 220 kV circuit for approximately 19 km. The sharing of towers means that both circuits have to be taken out at the same time. This has an impact on the security and capacity of the transmission network in Dublin, which is reflected in the technical and deliverability criteria. This option is considered to have high technical and deliverability impact (**Dark Blue**).

Economic Performance

A high level assessment of the estimated capital cost for up-voltaging the circuits in the southern section concluded that Dunstown – Maynooth 220 kV cricuit 1 have a high cost impact (**Dark Blue**), while both Dunstown – Maynooth 220 kV circuit 2 have a moderate cost impact (**Dark Green**) and Maynooth – Turlough Hill 220 kV have a high to moderate cost impact (**Blue**). The estimates range between €25-33m.

Environmental

Based on the information available at this stage, having considered the potential environmental impacts that may be associated with any up-oltage for the circuits in the southern section, it is concluded that the Dunstown – Maynooth 220 kV circuit 2 may have a moderate to low significance (**Green**) impact on environment when compared to Dunstown – Maynooth 220 kV circuit 1 and Maynooth – Turlough Hill 220 kV circuits which have been scored moderate impact (**Dark Green**). The alternatives perform very similarly overall and the impacts are mainly related to construction activities. The transmission lines traverse farmland in the main and do not cross areas of high environmental sensitivity such as European Sites etc. Peatland sites to west are avoided by all circuits. All the circuits oversail the Grand Canal and the River Liffey. Dunstown Maynooth circuit 1 crosses an area of ecological value (undesignated natural grassland) close to Dunstown Station which was considered in the scoring. The requirement for a short section of new infrastructure on the Maynooth Turlough Hill circuit contributes to its slightly lower scoring for environmental criteria.

Socio-economic

Maynooth – Turlough Hill 220 kV performs poorly against the socio-economic aspects. This is largely as a result of the circuit travelling through defined settlements, in particular Clane where recreation features are located. There will be an increased impact on landscape also due to the construction of new infrastructure for a short section. The impact to other criteria was not thought to be as significant. This option is considered to have moderate socio-economic impact (**Dark Green**).

Dunstown – Maynooth 220 kV circuit 1 performs low to moderate against socio-economic aspects. This is primarily as a result of not travelling in proximity to defined settlements, its low-moderate impact on the landscape and cultural heritage. The circuit does travel in proximity to Baldonnell Aerodrome. There are impacts expected to some recreation and tourism features due to the proximity of the circuit to these features,

however, this are not expected to be direct. This option is considered to have low to moderate socio-economic impact (**Green**).

Dunstown – Maynooth 220 kV circuit 2 performs low to moderate against socio-economic aspects. It does travel in proximity to defined settlements (Two Mile House). The impact on the landscape and cultural heritage is low-moderate. It is also significant distance from Baldonnell Aerodrome. There are low-moderate impacts expected to some recreation and tourism features due to the proximity of the circuit to these features, however, this are not expected to be direct. This option is considered to have low to moderate socio-economic impact (**Green**).

Conclusion

In the northern section the existing Gorman – Maynooth 220 kV circuit is the best performing option to use for the up-voltage option and in the southern section the best performing option is the existing Dunstown – Maynooth 220 kV circuit 2.

It should be noted that it is only part of the Gorman – Maynooth 220 kV that will be used for the up-voltage option in the northern section. The technology used to create the connection into Woodland station from the Gorman – Maynooth 220 kV circuit will be determined in Step 3 and the any required routing will be carried out in Step 4.

Appendix 2 – Analysis Result

Appendix 2A – Up-voltage existing 220 kV circuits to 400 kV OHL circuit

N-1 Overloads

Scenario	Contingency	Overloaded Circuit	Rating	Loading	%Loading
Winter Peak Export	Dunstown - Coolnabacky 400 kV	Bracklone –Portlaoise 110 kV circuit	128	146.5	112.0
Summer Peak Export	Dunstown - Coolnabacky 400 kV	Bracklone –Portlaoise 110 kV circuit	105	124.7	112.5

N-1-1 Overloads which remain following re-dispatch of generation

Maintenance	Contingency	Overloaded Circuit	Pre – Cnt	Post – Cnt	Rating (MVA)	Loading %	Potential candidate Solution
Dunstown - Coolnabacky 400 kV	Moneypoint - Oldstreet 400 kV	Coolnabacky – Portlaoise 110 kV	166.1	314.2	178	172	Additional capacity requirement
		Cashla - Prospect 220 kV	330.4	678.6	392	164.5	Additional capacity requirement
		Bracklone - Newbridge 110 kV	96.4	171.5	136	126.8	Additional capacity requirement
		Maynooth – Shannonbridge 220 kV	202.7	335.5	269	123.1	Additional capacity requirement
		Killonan – Shannonbridge 220 kV	249.7	389.1	269	139.9	Additional capacity requirement
		Cashla – Ennis 110 kV	130.9	201.3	178	111.5	Additional capacity requirement but related to Cashla Prospect overload above
		Bracklone –Portlaoise 110 kV	107.3	185.1	105	173.1	Additional capacity requirement
	Oldstreet – Woodland 400 kV	Coolnabacky – Portlaoise 110 kV	166.1	297.3	178	163.3	Same as above
		Maynooth – Shannonbridge 220 kV	202.7	381.2	269	140.4	Same as above
		Killonan – Shannonbridge 220 kV	249.7	388.1	269	139	Same as above
		Bracklone - Newbridge 110 kV	96.4	176.6	136	131.5	Same as above
		Cashla – Flagford 220 kV	204.5	463.1	405	112	Additional capacity requirement
		Bracklone –Portlaoise 110 kV	107.3	190.8	105	179.1	Same as above
	Cushaling – Portlaoise 110 kV	Bracklone –Portlaoise 110 kV	107.3	142	105	127.8	Same as above
	Dunstown – Kellis 220 kV	Bracklone –Portlaoise 110 kV	107.3	125.1	105	112.8	Same as above
	Maynooth – Shannonbridge 220 kV	Bracklone –Portlaoise 110 kV	107.3	122.5	105	110.4	Same as above
Coolnabacky – Moneypoint 400 kV	Oldstreet – Woodland 400 kV	Killonan – Shannonbridge 220 kV	269.3	438.3	269	173.6	Same as above
		Maynooth – Shannonbridge 220 kV	205.3	410.2	269	162.5	Same as above
		Cashla – Flagford 220 kV	214.4	544.4	405	137.5	Same as above
		Agannygal – Shannonbridge 110 kV	83.8	131.3	105	126.4	Additional capacity requirement
		Cashla - Prospect 220 kV	352.4	433.3	392	113	Same as above
	Moneypoint - Oldstreet 400 kV	Agannygal – Shannonbridge 110 kV	83.8	129.8	105	123.6	Same as above

		Cashla – Ennis 110 kV	138.1	234.6	178	131.7	Same as above
		Cashla - Prospect 220 kV	352.4	829.8	392	211.7	Same as above
		Killonan – Shannonbridge 220 kV	241.1	486.6	269	180.9	Same as above
		Maynooth – Shannonbridge 220 kV	177.3	394.6	269	146.7	Same as above
Moneypoint - Oldstreet 400 kV	Dunstown - Coolnabacky 400 kV	Coolnabacky – Portlaoise 110 kV	107	314.2	178	172	Same as above
		Bracklone –Portlaoise 110 kV	77.3	185	105	172.9	Same as above
		Cashla - Prospect 220 kV	352.6	679.1	392	164.6	Same as above
		Killonan – Shannonbridge 220 kV	241.1	389	269	139.8	Same as above
		Bracklone - Newbridge 110 kV	68	171.4	136	126.7	Same as above
		Maynooth – Shannonbridge 220 kV	177.3	334.9	269	122.9	Same as above
		Cashla – Ennis 110 kV	138.1	201.6	178	111.7	Same as above
	Coolnabacky – Moneypoint 400 kV	Agannygal – Shannonbridge 110 kV	83.8	129.8	105	123.6	Same as above
		Cashla – Ennis 110 kV	138.1	234.6	178	131.8	Same as above
		Cashla - Prospect 220 kV	352.4	830.5	392	211.9	Same as above
		Killonan – Shannonbridge 220 kV	241.1	484.8	269	180.2	Same as above
		Maynooth – Shannonbridge 220 kV	177.3	392.8	269	146	Same as above
	Dunstown – Woodland 400 kV	Maynooth – Woodland 220 kV cc1	219.2	633.4	434	140.9	Additional capacity requirement
		Cashla - Prospect 220 kV	352.6	552	392	133.1	Same as above
Cullenagh - Great 220kV Ckt 1	Cullenagh - Waterford 110 kV	Killoternan – Waterford 110 kV	58.6	173.7	99	169.4	Additional capacity requirement
	Butlerstown - Cullenagh 110 kV	Cullenagh - Waterford 110 kV	150.5	233	178	125.9	Additional capacity requirement
	Butlerstown – Killoternan 110kV	Cullenagh - Waterford 110 kV	150.5	213	178	115.1	Same as above
Cullenagh - Waterford 110kV Ckt 1	Cullenagh – Great Island 220kV	Killoternan – Waterford 110 kV	85.5	173.7	99	169.4	Same as above

Appendix 2B – New 400 kV OHL circuit

N-1 Overloads

Scenario	Contingency	Overloaded Circuit	Rating (MVA)	Loading (MVA)	Loading %
Winter Peak Export	Dunstown - Coolnabacky 400 kV	Bracklone –Portlaoise 110 kV	128	146.9	111.4
Summer Peak Export	Dunstown - Coolnabacky 400 kV	Bracklone –Portlaoise 110 kV	105	124.6	112.3

N-1-1 Overloads which remain following re-dispatch of generation

Maintenance	Contingency	Overloaded Circuit	Pre-Cnt	Post – Cnt	Rating (MVA)	Loading %	Potential candidate Solution
Dunstown - Coolnabacky 400 kV	Moneypoint – Oldstreet 400kV	Coolnabacky – Portlaoise 110 kV	165.9	312.7	178	171.3	Additional capacity requirement
		Cashla - Prospect 220 kV	327.4	670.7	392	162.4	Additional capacity requirement
		Killonan – Shannonbridge 220 kV	246.6	385.6	269	138.5	Additional capacity requirement
		Bracklone –Newbridge 110 kV	97.5	172.5	136	127.6	Additional capacity requirement
		Maynooth – Shannonbridge 220 kV	197.6	331.8	269	121.5	Additional capacity requirement
		Bracklone –Portlaoise 110 kV	108.5	186.1	105	174.1	Additional capacity requirement
		Cashla – Ennis 110 kV	129.9	199	178	110.1	Additional capacity requirement but related to Cashla Prospect overload above
	Oldstreet – Woodland 400kV	Coolnabacky – Portlaoise 110 kV	165.9	296.7	178	163.2	Same as above
		Bracklone –Portlaoise 110 kV	108.5	192	105	180.5	Same as above
		Maynooth – Shannonbridge 220 kV	197.6	379.3	269	139.6	Same as above
		Killonan – Shannonbridge 220 kV	246.6	386	269	138.2	Same as above
		Bracklone - Newbridge 110 kV	97.5	177.9	136	132.5	Same as above
	Cushalin – Portlaoise 110 kV	Bracklone –Portlaoise 110 kV	108.5	143.6	105	129.3	Same as above
	Dunstown – Kellis 220 kV	Bracklone –Portlaoise 110 kV	108.5	127.5	105	114.9	Same as above
	Maynooth – Shannonbridge 220 kV	Bracklone –Portlaoise 110 kV	108.5	122.5	105	110.4	Same as above
Coolnabacky – Moneypoint 400 kV	Oldstreet – Woodland 400kV	Killonan – Shannonbridge 220 kV	266.6	468.6	269	172.4	Same as above
		Maynooth – Shannonbridge 220 kV	200	409.5	269	161	Same as above
		Cashla – Flagford 220 kV	210.7	534.6	405	134.3	Additional capacity requirement
		Agannygal – Shannonbridge 110kV	83.8	131.6	105	126	Additional capacity requirement
		Cashla - Prospect 220 kV	350.4	429.2	392	111.4	Same as above
	Moneypoint – Oldstreet 400kV	Cashla - Prospect 220 kV	350.4	754	392	209.3	Same as above
		Killonan – Shannonbridge 220 kV	266.6	475.5	269	179.2	Same as above
		Maynooth – Shannonbridge 220 kV	200	360.2	269	144.5	Same as above
		Cashla – Ennis 110 kV	131.6	219	178	130	Same as above
		Agannygal – Shannonbridge 110kV	83.8	123.5	105	123.2	Same as above

Moneypoint – Oldstreet 400kV	Dunstown - Coolnabacky 400 kV	Coolnabacky – Portlaoise 110 kV	100.7	312.7	178	171.2	Same as above
		Bracklone –Portlaoise 110 kV	75.9	186	105	173.9	Same as above
		Cashla - Prospect 220 kV	340.4	671.3	392	162.6	Same as above
		Killonan – Shannonbridge 220 kV	231.9	385.5	269	138.4	Same as above
		Bracklone - Newbridge 110 kV	66.5	172.4	136	127.5	Same as above
		Maynooth – Shannonbridge 220 kV	164.1	331.1	269	121.3	Same as above
		Cashla – Ennis 110 kV	135.1	199.2	178	110.3	Same as above
	Dunstown – Woodland 400kV	Cashla - Prospect 220 kV	340.4	480.3	392	115.4	Same as above
		Maynooth – Woodland 220 kV crt1	234.5	524.2	434	120.8	Additional capacity requirement
	Coolnabacky – Moneypoint 400 kV	Cashla - Prospect 220 kV	340.4	754.5	392	209.3	Same as above
		Killonan – Shannonbridge 220 kV	231.9	475.3	269	179	Same as above
		Maynooth – Shannonbridge 220 kV	164.1	359.8	269	144.2	Same as above
		Cashla – Ennis 110 kV	135.1	219.2	178	130.1	Same as above
		Agannygal – Shannonbridge 110kV	74.1	123.5	105	123.1	Same as above
Cullenagh - Great Island 220kV	Cullenagh - Waterford 110 kV	Killoternan – Waterford 110 kV	60.6	178.7	99	174.5	Additional capacity requirement
	Butlerstown - Cullenagh 110 kV	Cullenagh - Waterford 110 kV	154.2	238.6	178	129	Additional capacity requirement
	Butlerstown – Killoternan 110kV	Cullenagh - Waterford 110 kV	154.2	218.6	178	118.3	Same as above
Cullenagh - Waterford 110kV	Cullenagh - Great Island 220kV	Killoternan – Waterford 110 kV	87.4	178.8	99	174.5	Same as above

Appendix 2C – New 220 kV OHL circuit

N-1 Overloads

Scenario	Contingency	Overloaded Circuit	Rating (MVA)	Loading (MVA)	Loading (%)
Winter Peak Export	Coolnabacky – Dunstown 400 kV	Bracklone –Portlaoise 110 kV	128	146.7	111
Summer Peak Export	Coolnabacky – Dunstown 400 kV	Bracklone –Portlaoise 110 kV	105	124.5	112.3
Summer Peak Export	Moneypoint – Oldstreet 400 kV	Cashla – Prospect 220 kV	392	489.1	117.9

N-1-1 Overloads which remain following re-dispatch of generation

Maintenance	Contingency	Overloaded Circuit	Pre-Cnt	Post Cnt	Rating (MVA)	Loading (%)	Potential candidate Solution
Dunstown - Coolnabacky 400 kV	Moneypoint – Oldstreet 400kV	Coolnabacky – Portlaoise 110 kV	164.5	312.6	178	170.9	Additional capacity requirement
		Killonan – Shannonbridge 220 kV	245.6	382.9	269	137.5	Additional capacity requirement
		Bracklone - Newbridge 110 kV	96.9	171.1	136	126.4	Additional capacity requirement
		Maynooth – Shannonbridge 220 kV	196.4	324.8	269	118.9	Additional capacity requirement
		Cashla – Ennis 110 kV	129.7	202.9	178	112.4	Additional capacity requirement but related to Cashla Prospect overload above
		Bracklone –Portlaoise 110 kV	107.7	184.7	105	172.4	Additional capacity requirement
		Cashla – Prospect 220 kV	320.2	649.8	392	165.8	Additional capacity requirement
	Oldstreet – Woodland 400kV	Bracklone –Portlaoise 110 kV	107.7	192.1	105	180.7	Same as above
		Coolnabacky – Portlaoise 110 kV	164.5	298.4	178	164.1	Same as above
		Maynooth – Shannonbridge 220 kV	196.4	376.1	269	138.6	Same as above
		Killonan – Shannonbridge 220 kV	245.6	385.4	269	138	Same as above
		Bracklone - Newbridge 110 kV	96.9	177.8	136	132.7	Same as above
		Cashla – Flagford 220 kV	197.9	460.6	405	111.5	Additional capacity requirement
	Cushalin – Portlaoise 110 kV	Bracklone –Portlaoise 110 kV	107.7	142.7	105	128.4	Same as above
	Dunstown – Kellis 220 kV	Bracklone –Portlaoise 110 kV	107.7	128	105	115.4	Same as above
	Maynooth – Shannonbridge 220 kV	Bracklone –Portlaoise 110 kV	107.7	122.2	105	110.1	Same as above
Coolnabacky – Moneypoint 400 kV	Oldstreet – Woodland 400kV	Killonan – Shannonbridge 220 kV	266.7	433.3	269	174.8	Same as above
		Cashla – Flagford 220 kV	209.8	548.1	405	140.3	Same as above
		Cashla - Prospect 220 kV	342.2	449.5	392.0	114.7	Same as above
		Maynooth – Shannonbridge 220 kV	197.8	442.2	269	164.4	Same as above
		Agannygal – Shannonbridge 110kV	83.9	130.3	105	127.3	Additional capacity requirement
	Cullenagh – Knockraha 220 kV	Killonan – Shannonbridge 220 kV	260.3	296	269	110.1	Same as above
		Moneypoint – Oldstreet 400 kV	1133.2	1141.6	997	114.5	Uprate CTs to match line ratings
		Oldstreet – Woodland 400 kV	1118.3	1168.5	997	117.2	Uprate CTs to match line ratings

	Moneypoint - Oldstreet 400 kV	Maynooth – Shannonbridge 220 kV	187	355.3	269	144.8	Same as above
		Cashla – Ennis 110 kV	159.9	224.8	178	134.9	Same as above
		Agannygal – Shannonbridge 110kV	83.9	129.5	105	123.4	Same as above
		Athlone – Lanesboro 110 kV	70.0	117.3	105	111.7	Additional capacity requirement
		Cashla – Prospect 220 kV	342.2	848.2	392	216.4	Same as above
		Killonan – Shannonbridge 220 kV	266.7	484.7	269	180.2	Same as above
Moneypoint – Oldstreet 400kV	Dunstown - Coolnabacky 400 kV	Bracklone –Portlaoise 110 kV	97.7	184.6	105	172.3	Same as above
		Cashla - Prospect 220 kV	326.7	683.9	392	165.6	Same as above
		Coolnabacky – Portlaoise 110 kV	148.4	312.2	178	170.5	Same as above
		Killonan – Shannonbridge 220 kV	260.3	382.6	269	137.3	Same as above
		Cashla – Ennis 110 kV	159.9	200.3	178	112.5	Same as above
		Bracklone - Newbridge 110 kV	87.7	171	136	126.2	Same as above
		Maynooth – Shannonbridge 220 kV	187	319.7	269	118.9	Same as above
	Dunstown – Woodland 220 kV	Cashla – Prospect 220 kV	435.3	451.3	392	115.1	Same as above
		Maynooth – Woodland 220 kV	347.2	525.3	434	121	Additional capacity requirement
	Coolnabacky – Moneypoint 400 kV	Cashla – Ennis 110 kV	159.9	237.1	178	133.2	Same as above
		Agannygal – Shannonbridge 110kV	77.8	127.1	105	121	Same as above
		Cashla – Prospect 220 kV	435.3	834.7	392	212.9	Same as above
		Killonan – Shannonbridge 220 kV	260.3	471.2	269	177.4	Same as above
		Maynooth – Shannonbridge 220 kV	187	355.3	269	142.4	Same as above
	2202 DUNSTOWN TRAFO CKT 1	Cashla – Prospect 220 kV	435.3	454.4	392	115.9	Same as above
		2204 DUNSTOWN TRAFO no.2	467.8	746.8	500	149.4	Third Dunstown 400/220 kV trafo required
	2202 DUNSTOWN TRAFO CKT 2	Cashla – Prospect 220 kV	435.3	457.5	392	116.7	Same as above
		2204 DUNSTOWN TRAFO no.1	441.2	743	500	148.6	Third Dunstown 400/220 kV trafo required
	Cashla - Prospect 220 kV	Cashla – Ennis 110 kV	159.9	239.2	178	132.2	Same as above
		Killonan – Shannonbridge 220 kV	260.3	314.1	269	111.6	Same as above
	2962 HUNTSTOWN TRAFO CKT 1	Cashla – Prospect 220 kV	447.2	463.7	392	111.3	Same as above
	3551 LAOIS TRAFO CKT 1	Cashla – Prospect 220 kV	447.2	459.3	392	110.1	Same as above
	5462 WOODLAND TRAFO CKT 1	Cashla – Prospect 220 kV	447.2	463.4	392	111.2	Same as above
	5462 WOODLAND TRAFO CKT 4	Cashla – Prospect 220 kV	447.2	463.4	392	111.2	Same as above
	Arklow – Lodgewood 220 kV	Cashla – Prospect 220 kV	447.2	458.6	392	110.1	Same as above
	Athlone – Shannonbridge 110 kV	Cashla – Prospect 220 kV	447.2	466.2	392	112	Same as above
	Booltiag – Ennis 110 kV	Cashla – Prospect 220 kV	447.2	465.2	392	111.7	Same as above
	Cashla – Ennis 110 kV	Cashla – Prospect 220 kV	447.2	506.6	392	121.8	Same as above
	Cashla – Somrst T 110 kV	Cashla – Prospect 220 kV	447.2	459.1	392	110.1	Same as above
	Corduff – Huntstown 220 kV	Cashla – Prospect 220 kV	447.2	459.9	392	110.4	Same as above
	Cullenagh – Knockraha 220 kV	Cashla – Prospect 220 kV	447.2	466.4	392	112.3	Same as above
	Cushalin – Portlaoise 110 kV	Bracklone –Portlaoise 110 kV	97.7	129	105	117.7	Same as above
	Dunstown – Maynooth 220 kV	Cashla – Prospect 220 kV	447.2	461.3	392	110.7	Same as above
	Finglas – Huntstown 220 kV	Cashla – Prospect 220 kV	447.2	463.8	392	111.3	Same as above
	Gorman – Louth 220 kV	Cashla – Prospect 220 kV	447.2	459.6	392	110.3	Same as above
	Gorman – Maynooth 220 kV	Cashla – Prospect 220 kV	447.2	473.6	392	113.7	Same as above
	Great Island – Lodgewood 220 kV	Cashla – Prospect 220 kV	447.2	460	392	110.5	Same as above
	Inchicore - Irishtown 220 k	Cashla – Prospect 220 kV	447.2	461.5	392	110.8	Same as above
	Killonan - Shannonbridge 220 kV	Cashla – Prospect 220 kV	447.2	485	392	116.6	Same as above
	Coolnabacky - Portlaoise 110 kV	Cashla – Prospect 220 kV	447.2	460.7	392	110.5	Same as above
	Maynooth – Woodland 220 kV	Cashla – Prospect 220 kV	447.2	466	392	111.9	Same as above

	Shannonbridge – Somrst T 110 kV	Cashla – Prospect 220 kV	447.2	462.8	392	111	Same as above
Cullenagh - Great Island 220kV	Cullenagh - Waterford 110kV	Killoternan – Waterford 110 kV	60.8	179	99	174.6	Additional capacity requirement
	Butlerstown - Cullenagh 110 kV	Cullenagh - Waterford 110kV	154.4	229.8	178	129.1	Additional capacity requirement
	Butlerstown – Killoternan 110kV	Cullenagh - Waterford 110kV	154.4	210.6	178	118.3	Same as above
Cullenagh - Waterford 110kV Ckt 1	Cullenagh - Great Island 220kV	Killoternan – Waterford 110 kV	87.1	172.9	99	174.7	Same as above

Appendix 2D – New 220 kV UGC

N-1 Overloads

Scenario	Contingency	Overloaded Circuit	Rating (MVA)	Loading (MVA)	Loading (%)
Winter Peak Export	Dunstown- Coolnabacky 400 kV	Bracklone –Portlaoise 110 kV circuit	128	150	113.3
Summer Peak Export	Dunstown- Coolnabacky 400 kV	Bracklone –Portlaoise 110 kV circuit	105	127.2	114.6
Summer Peak Export	Moneypoint – Oldstreet 400 kV	Cashla – Prospect 220 kV circuit	392	468	112.6
Summer Peak Export	Coolnabacky –Moneypoint 400 kV	Killonan – Shannonbridge 220 kV circuit	267	311.4	110.4

N-1-1 Overloads which remain following re-dispatch of generation

Maintenance	Contingency	Overloaded Circuit	Pre-Cnt	Post-Cnt	Rating (MVA)	Loading (%)	Potential candidate Solution
Dunstown - Coolnabacky 400 kV	Moneypoint – Oldstreet 400kV	Coolnabacky – Portlaoise 110 kV	167.5	312.6	178	170.4	Additional capacity requirement
		Killonan – Shannonbridge 220 kV	249.7	371.1	269	137.9	Additional capacity requirement
		Bracklone - Newbridge 110 kV	99.3	172.7	136	126.8	Additional capacity requirement
		Maynooth – Shannonbridge 220 kV	202.4	330.5	269	120.4	Additional capacity requirement
		Bracklone –Portlaoise 110 kV	109.9	185.8	105	172.8	Additional capacity requirement
		Cashla - Prospect 220 kV	327.4	672.7	392	162.9	Additional capacity requirement
		Cashla – Ennis 110 kV	129.5	199.6	178	110.4	Additional capacity requirement but related to Cashla Prospect overload above
	Oldstreet – Woodland 400kV	Coolnabacky – Portlaoise 110 kV	167.5	296.6	178	162.6	Same as above
		Bracklone –Portlaoise 110 kV	109.9	191.9	105	179.7	Same as above
		Maynooth - Shannonbridge 220 kV	202.4	378.5	269	138.7	Same as above
		Killonan - Shannonbridge 220 kV	249.7	370.7	269	137.8	Same as above
		Bracklone - Newbridge 110 kV	99.3	178.2	136	132	Same as above
	Cushalin – Portlaoise 110 kV	Bracklone –Portlaoise 110 kV	109.9	145.3	105	130.8	Same as above
	Dunstown – Kellis 220 kV	Bracklone –Portlaoise 110 kV	109.9	129.2	105	116.5	Same as above
	Maynooth – Shannonbridge 220 kV	Bracklone –Portlaoise 110 kV	109.9	124.8	105	112.4	Same as above
Coolnabacky –Moneypoint 400 kV	Oldstreet – Woodland 400kV	Maynooth – Shannonbridge 220 kV	206	415.1	269	160.3	Same as above
		Cashla – Flagford 220 kV	213.6	534.4	405	133.6	Additional capacity requirement
		Agannygal – Shannonbridge 110kV	84.7	131.1	105	124.1	Additional capacity requirement
		Killonan – Shannonbridge 220 kV	270.8	467.6	269	171.1	Same as above
		Cashla - Prospect 220 kV	350.9	428	392	110.5	Same as above
	Cullenagh – Knockraha 220 kV	Killonan – Shannonbridge 220 kV	213.9	299.4	269	111.3	Same as above

	Moneypoint – Oldstreet 400kV	Maynooth – Shannonbridge 220 kV	206	365	269	141.6	Same as above
		Cashla – Ennis 110 kV	131.2	220.2	178	127.9	Same as above
		Agannygal – Shannonbridge 110kV	84.7	123.4	105	119.7	Same as above
		Killonan – Shannobridge 220 kV	270.8	473	269	175.6	Same as above
		Cashla - Prospect 220 kV	350.9	759.9	392	205.7	Same as above
	Cullenagh – Knockraha 220 kV	Killonan – Shannobridge 220 kV	270.8	313.1	269	111.3	Same as above
		Moneypoint – Oldstreet 400 kV	1136.2	1141.6	997	114	Uprate CTs to match line ratings
		Oldstreet – Woodland 400 kV	1118.3	1159.8	997	116.3	Uprate CTs to match line ratings
Moneypoint – Oldstreet 400kV	Dunstown - Coolnabacky 400 kV	Coolnabacky – Portlaoise 110 kV	144.7	312.8	178	169.9	Same as above
		Bracklone –Portlaoise 110 kV	97.2	185.9	105	172.3	Same as above
		Bracklone - Newbridge 110 kV	87.3	172.7	136	126.4	Same as above
		Maynooth – Shannonbridge 220 kV	190.7	329.8	269	119.9	Same as above
		Cashla – Ennis 110 kV	154.9	200.2	178	110.5	Same as above
		Cashla - Prospect 220 kV	427.8	672.3	392	162.7	Same as above
		Killonan – Shannonbridge 220 kV	260.3	383.9	269	137.6	Same as above
	Dunstown - Woodland 220 kV	Maynooth – Woodland 220 kV ckt1	333.7	521.9	434	115.4	Additional capacity requirement
		Cashla - Prospect 220 kV	427.8	494	392	118.7	Same as above
	Coolnabacky –Moneypoint 400 kV	Maynooth – Shannonbridge 220 kV	190.7	364.2	269	140.1	Same as above
		Cashla – Ennis 110 kV	154.9	222.2	178	127.8	Same as above
		Agannygal – Shannonbridge 110kV	78.2	123.4	105	118.5	Same as above
		Killonan – Shannonbridge 220 kV	260.3	471.5	269	174.2	Same as above
		Cashla - Prospect 220 kV	427.8	766.8	392	204.6	Same as above
	2202 DUNSTOWN TRAFO CKT 1	2204 DUNSTOWN TRAFO no.2	487.2	768.5	500	153.7	Third Dunstown 400/220 kV trafo required
		Cashla - Prospect 220 kV	427.8	464.4	392	111.4	Same as above
	2204 DUNSTOWN TRAFO CKT 2	2204 DUNSTOWN TRAFO no.1	444.7	756.9	500	151.4	Same as above
		Cashla - Prospect 220 kV	427.8	468.2	392	112.3	Same as above
	Cashla - Prospect 220 kV	Cashla – Ennis 110 kV	154.9	228.6	178	125.9	Same as above
		Killonan – Shannobridge 220 kV	260.3	310.8	269	110.2	Same as above
	Cashla – Ennis 110 kV	Cashla - Prospect 220 kV	427.8	484.1	392	116.2	Same as above
	5464 WOODLAND TRAFO CKT 1	Maynooth – Woodland 220 kV crt1	333.7	514.9	434	112.8	Same as above
		Cashla - Prospect 220 kV	427.8	490.5	392	117.8	Same as above
	Cushalin – Portlaoise 110 kV	Bracklone –Portlaoise 110 kV	97.2	128.1	105	116.5	Same as above
	Killonan – Shannonbridge 220 kV	Cashla - Prospect 220 kV	427.8	464.9	392	111.7	Same as above
Cullenagh - Great Island 220kV	Cullenagh - Waterford 110kV	Killoternan – Waterford 110 kV	61.8	181.3	99	176.9	Additional capacity requirement
	Butlerstown - Cullenagh 110 kV	Cullenagh - Waterford 110kV	156.1	241.3	178	130.5	Additional capacity requirement
	Butlerstown – Killoternan 110kV	Cullenagh - Waterford 110kV	156.1	221.4	178	119.7	Same as above
	Killoternan – Waterford 110 kV	Cullenagh - Waterford 110kV	156.1	205.2	178	111.2	Same as above
	Cullenagh - Waterford 110kV	Butlerstown - Cullenagh 110 kV	99.4	221.3	192	110.8	Additional capacity requirement
Cullenagh - Waterford 110kV Ckt 1	Cullenagh - Great Island 220kV	Killoternan – Waterford 110 kV	88.2	181.4	99	176.9	Same as above
		Butlerstown - Cullenagh 110 kV	127.5	221.3	192	110.8	Same as above

Appendix 2E – New 400 kV UGC circuit

N-1 Overloads

Scenario	Contingency	Overloaded Circuit	Rating (MVA)	Loading (MVA)	Loading (%)
Winter Peak Export	Dunstown - Coolnabacky 400 kV	Bracklone –Portlaoise 110 kV circuit	128	146.6	110.6
Summer Peak Export	Dunstown - Coolnabacky 400 kV	Bracklone –Portlaoise 110 kV circuit	105	124.5	112.2

N-1-1 Overloads which remain following re-dispatch of generation

Maintenance	Contingency	Overloaded Circuit	Pre-Cnt	Post–Cnt	Rating (MVA)	Loading (%)	Potential candidate Solution
Dunstown - Coolnabacky 400 kV	Moneypoint – Oldstreet 400kV	Coolnabacky – Portlaoise 110 kV	165	312.3	178	170.2	Additional capacity requirement
		Cashla - Prospect 220 kV	326	665.2	392	160.9	Additional capacity requirement
		Killonan – Shannonbridge 220 kV	247.1	385.5	269	138.2	Additional capacity requirement
		Bracklone - Newbridge 110 kV	97.6	173.1	136	127.1	Additional capacity requirement
		Bracklone –Portlaoise 110 kV	108.3	186.4	105	173.3	Additional capacity requirement
		Maynooth – Shannonbridge 220 kV	199	333.6	269	121.6	Additional capacity requirement
	Oldstreet – Woodland 400kV	Coolnabacky – Portlaoise 110 kV	165	296.2	178	162	Same as above
		Maynooth – Shannonbridge 220 kV	199	380.5	269	139.2	Same as above
		Bracklone –Portlaoise 110 kV	108.3	192.1	105	179.5	Same as above
		Killonan – Shannonbridge 220 kV	247.1	385.7	269	137.9	Same as above
		Bracklone - Newbridge 110 kV	97.6	178.4	136	131.8	Same as above
	Cushalin – Portlaoise 110 kV	Bracklone –Portlaoise 110 kV	108.3	143.2	105	128.7	Same as above
	Dunstown – Kellis 220 kV	Bracklone –Portlaoise 110 kV	108.3	127.2	105	114.6	Same as above
	Maynooth - Shannonbridge 220 kV	Bracklone –Portlaoise 110 kV	108.3	122.3	105	110.1	Same as above
Coolnabacky – Moneypoint 400 kV	Oldstreet – Woodland 400kV	Killonan – Shannonbridge 220 kV	267	467.5	269	170.9	Same as above
		Maynooth – Shannonbridge 220 kV	200.8	412.3	269	158.7	Same as above
		Cashla – Flagford 220 kV	209.9	527.2	405	131.3	Additional capacity requirement
		Agannygal – Shannonbridge 110kV	84	132.1	105	124.8	Additional capacity requirement
	Moneypoint – Oldstreet 400kV	Cashla - Prospect 220 kV	349.4	821.3	392	202	Same as above
		Killonan – Shannonbridge 220 kV	267	473.1	269	174.7	Same as above
		Maynooth – Shannonbridge 220 kV	200.8	364.7	269	140.1	Same as above
		Cashla – Ennis 110 kV	131.3	218.2	178	125.4	Additional capacity requirement but related to Cashla Prospect overload above
		Agannygal – Shannonbridge 110kV	84	124.8	105	119.7	Same as above
Moneypoint – Oldstreet 400kV	Dunstown - Coolnabacky 400kV	Coolnabacky – Portlaoise 110 kV	89.8	312.3	178	170.2	Same as above
		Cashla - Prospect 220 kV	318.9	666	392	161.1	Same as above
		Bracklone –Portlaoise 110 kV	71.2	186.2	105	173.2	Same as above
		Killonan – Shannonbridge 220 kV	226.5	385.4	269	138.2	Same as above

		Bracklone - Newbridge 110 kV	61.8	172.9	136	127	Same as above
		Maynooth – Shannonbridge 220 kV	160.2	332.8	269	121.3	Same as above
	Dunstown – Woodland 400kV	Maynooth – Woodland 220 kV crt1	152.7	547.3	434	120.7	Additional capacity requirement
		Cashla - Prospect 220 kV	318.9	480.5	392	115.5	Same as above
	Coolnabacky –Moneypoint 400 kV	Cashla - Prospect 220 kV	318.9	822	392	202.1	Same as above
		Killonan – Shannonbridge 220 kV	226.5	472.9	269	174.7	Same as above
		Cashla – Ennis 110 kV	130.1	218.4	178	125.6	Same as above
		Agannygal – Shannonbridge 110kV	73.4	124.7	105	119.7	Same as above
		Maynooth – Shannonbridge 220 kV	160.2	364.1	269	139.8	Same as above
Cullenagh – Great Island 220kV	Cullenagh - Waterford 110kV	Killoternan – Waterford 110 kV	61.3	180.1	99	175.6	Additional capacity requirement
		Butlerstown - Cullenagh 110 kV	98.9	220	192	110.2	Additional capacity requirement
	Butlerstown - Cullenagh 110 kV	Cullenagh - Waterford 110kV	155.2	239.9	178	129.7	Additional capacity requirement
	Butlerstown – Killoternan 110kV	Cullenagh - Waterford 110kV	155.2	220	178	118.9	Same as above
	Killoternan – Waterford 110 kV	Cullenagh - Waterford 110kV	155.2	203.8	178	110.4	Same as above
Cullenagh - Waterford 110kV Ckt 1	Cullenagh – Great Island 220kV	Killoternan – Waterford 110 kV	88.3	180.1	99	175.7	Same as above
		Butlerstown - Cullenagh 110 kV	127.7	220	192	110.2	Same as above

Appendix 3 – Reactive support requirements

The needs assessment (Step 1) for CP0966 identified voltage stability problems. The requirement for reactive support has been analysed as part of the solution options to solve the voltage instability. The amount of reactive support required depends on how much additional demand connects on the East coast and how much of this demand is met by remote generation in the west and south west of Ireland.
To determine the amount of reactive support required for each of the solution options we used two criteria. The first criterion is to meet the need based on the assumptions set out in Step 1. In Step 1 the assumptions were for approximately 900 MW of additional demand in the counties Kildare, Meath and Dublin. This was based on executed and offered connection agreements at that point in time.

The second criterion is to meet further demand on the East coast that could materialise in the future. Ireland is currently experiencing an increased interest in connecting large scale demand on the East coast and the options were assessed based on their capability of accommodating this. Increased demand results in higher levels of reactive power load as well as higher power transfers particularly on the existing 400 kV lines, running from the west to the east. A transfer on the 400 kV circuits, running from the west to the east, of approximately 2200 MVA was modelled. With the generation assumptions in the analysis, this equates to approximately 1400 MW additional demand on the East coast. This target included the approximately 900 MW offered and executed demand connection agreements in Kildare, Meath and Dublin, leaving a margin of additional demand of 500 MW available. The 500 MW demand margin was deemed prudent for assessing the options against. It should be noted that this margin could be further increased using additional reactive support or generation in the eastern part of the network.

PV analysis was used to assess the impact that increasing power transfers would have on voltage stability. To test this, generation sources were increased in the west and south west to meet increasing demand on the East coast.

A three phase process was used in reactive support solution planning for each of the five network reinforcement options. These were:

1. Identify successive network limitations for increasing levels of power transfer;
2. Identify best performing solution locations;

3. Determine solution plan (total volumes needed applied to best performing locations) for specific demand and transfer levels.

The first phase increased power transfers until each successive network limitation is reached.As transfers are increased the voltage is pulled down until voltage collapse is reached. By monitoring the changes in reactive power draw on both lines and demand the locations and amounts of needed reactive support to restore voltage to the original condition can be identified. The shortages can then be addressed before increasing transfers again and repeating the process.

The second phase was a comparison of the effectiveness of different locations. Sources of reactive power are added to individual nodes in turn and power transfer levels recorded.

Finally, needed levels of reactive support were tested among multiple locations to determine the number of installations (at specific volumes) needed to reach certain power transfer levels.

It was found that the 400 kV underground cable option creates the most transfer margin. This is largely due to the characteristics of the cable which contributes reactive power to the network. A new 400 kV overhead line and 400 kV up-voltage options perform similarly relatively to each other but not as well as the 400 kV underground cable option. The 220 kV options create the least amount of transfer margin although the 220 kV underground cable option performs better than the 220 kV overhead line option.

Appendix 4 – Short Circuit Results

The following tables give the short circuit results for the options in the refined long list.

Appendix 4A – Base Case (no options)

			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	31.1803	37.1	59%	13.7163	55%	15.2904	61%	28.7349	28.8829	46%	10.4918	42%	12.2533	49%
BELCAMP	220	40	12.7162	64.2	64%	25.3193	63%	24.4435	61%	10.1076	69.4607	69%	26.6196	67%	27.913	70%
CARRICKMINES	110	26.2	28.4771	36.8	56%	13.6772	52%	14.7078	56%	23.1081	38.291	58%	13.8676	53%	15.4724	59%
CARRICKMINES	220	40	11.5807	58.7	59%	23.352	58%	22.3836	56%	7.9824	64.483	64%	25.6306	64%	26.1775	65%
CORDUFF	110	31.5	9.0135	60.0	76%	24.6365	78%	22.4231	71%	10.6107	61.6596	78%	23.9622	76%	24.1859	77%
CORDUFF	220	40	14.7657	71.8	72%	27.9095	70%	27.8577	70%	12.5789	77.128	77%	28.8272	72%	31.3598	78%
DUNSTOWN	220	40	6.4771	56.8	57%	24.5458	61%	22.8455	57%	7.3921	59.3488	59%	24.3751	61%	24.7406	62%
DUNSTOWN	380	50	3.3873	22.2	18%	11.0126	22%	10.4704	21%	4.7403	24.0304	19%	10.8422	22%	10.8571	22%
FIN_URBAN	110	31.5	35.1347	41.1	52%	15.1491	48%	17.2004	55%	30.7021	49.4424	63%	17.5317	56%	20.9255	66%
FINGLAS	220	40	15.7452	71.0	71%	27.4208	69%	27.721	69%	14.4079	80.9408	81%	29.7034	74%	33.2687	83%
FIN_RURAL	110	31.5	33.5536	41.0	52%	15.1195	48%	16.626	53%	27.6828	42.938	55%	15.2016	48%	17.727	56%
INCH_CITY	110	31.5	27.4702	42.9	54%	15.9821	51%	16.9384	54%	24.0457	52.2014	66%	18.688	59%	21.0726	67%
INCHICORE	220	40	11.5125	71.3	71%	28.3977	71%	26.7213	67%	8.525	77.9185	78%	30.4334	76%	31.2784	78%
INCH_COUNTRY	110	31.5	41.6135	43.2	55%	15.7962	50%	18.5621	59%	31.8943	52.5002	67%	18.4288	59%	22.2607	71%
IRISHTOWN	220	40	12.6608	66.9	67%	26.38	66%	25.4547	64%	10.1359	76.1203	76%	29.0896	73%	30.5219	76%
WEST DUBLIN	110	31.5	21.7218	49.6	63%	18.7119	59%	18.9896	60%	23.1481	36.1966	46%	13.2998	42%	14.8023	47%
WEST DUBLIN	220	40	9.2593	67.5	68%	27.6122	69%	25.5237	64%	8.2956	63.4008	63%	25.2836	63%	25.8976	65%
MAYNOOTH A	110	31.5	10.0312	36.8	47%	14.8844	47%	14.0978	45%	10.782	43.5727	55%	17.0617	54%	17.2302	55%
MAYNOOTH B	220	40	7.9751	52.7	53%	22.0211	55%	20.7257	52%	8.6395	41.7766	42%	16.8651	42%	17.3238	43%
MAYNOOTH B	110	31.5	7.5459	45.2	57%	19.0466	60%	17.9487	57%	9.1639	43.0394	55%	17.2974	55%	17.3718	55%
MAYNOOTH A	220	40	8.4558	62.5	62%	25.8733	65%	24.3041	61%	8.5399	51.4654	51%	20.7365	52%	21.2811	53%
POOLBEG	110	40	26.3863	43.5	43%	16.2279	41%	17.0791	43%	21.0509	52.0708	52%	18.8395	47%	20.6432	52%
POOLBEG NORT	220	31.5	13.4914	63.0	80%	24.6709	78%	24.2277	77%	6.6883	54.9122	70%	22.5437	72%	22.7678	72%
POOLBEG	110	40	26.3536	43.4	43%	16.1917	40%	17.0366	43%	21.0388	51.975	52%	18.8059	47%	20.604	52%
POOLBEG SOUT	220	31.5	11.4261	65.5	83%	26.1067	83%	24.7517	79%	8.5567	66.4059	84%	26.1425	83%	26.8661	85%
SHELLYBANKS	220	40	13.1832	62.7	63%	24.639	62%	24.0663	60%	8.1554	60.0519	60%	23.8312	60%	24.3818	61%
SHELLYBANKS	220	40	12.3372	64.1	64%	25.3415	63%	24.3911	61%	8.83	70.6667	71%	27.5629	69%	28.4244	71%
SHELLYBANKSB	220	40	12.3372	64.1	64%	25.3415	63%	24.3911	61%	8.83	70.6667	71%	27.5629	69%	28.4244	71%
WOODLAND	220	40	11.5873	68.8	69%	27.4022	69%	27.0176	68%	11.7713	67.9009	68%	26.1832	65%	28.0447	70%
WOODLAND	380	40	13.2077	35.7	36%	14.0031	35%	13.0818	33%	13.441	37.1549	37%	14.2205	36%	14.2205	36%

Appendix 4B – Up-voltage existing 220 kV circuits to 400 kV OHL circuit

			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%	28.6	28.9	46%	10.5	42%	12.3	49%
BELCAMP	220	40	12.4	64.8	65%	22.4	56%	24.6	61%	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%	22.4	56%	8.3	64.3	64%	25.4	63%	26.0	65%
CORDUFF	110	31.5	9.0	59.8	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	54.8	55%	20.9	52%	21.6	54%	9.2	59.6	60%	23.7	59%	24.5	61%
DUNSTOWN	380	50	5.1	33.0	26%	14.1	28%	14.1	28%	6.2	33.3	27%	14.3	29%	14.3	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%	30.0	75%	33.5	84%
FIN_RURAL	110	31.5	33.2	41.1	52%	13.2	42%	16.6	53%	27.5	43.0	55%	15.2	48%	17.7	56%
INCH_CITY	110	31.5	28.4	42.7	54%	14.2	45%	17.0	54%	24.7	52.0	66%	18.6	59%	21.1	67%
INCHICORE	220	40	12.4	70.0	70%	24.0	60%	26.4	66%	8.9	77.0	77%	29.8	75%	30.8	77%
INCH_COUNTRY	110	31.5	43.6	43.0	55%	13.9	44%	18.7	59%	32.9	52.4	66%	18.3	58%	22.3	71%
IRISHTOWN	220	40	13.6	66.3	66%	22.6	57%	25.4	64%	10.6	75.7	76%	28.7	72%	30.3	76%
WEST DUBLIN	110	31.5	22.1	48.9	62%	16.8	53%	18.7	59%	23.4	36.1	46%	13.2	42%	14.8	47%
WEST DUBLIN	220	40	9.8	64.5	65%	23.2	58%	24.4	61%	8.6	62.3	62%	24.7	62%	25.4	63%
MAYNOOTH A	110	31.5	9.8	36.0	46%	13.7	44%	13.8	44%	10.6	43.3	55%	16.9	54%	17.1	54%
MAYNOOTH B	220	40	8.4	47.0	47%	18.0	45%	18.5	46%	8.7	42.4	42%	17.1	43%	17.5	44%
MAYNOOTH B	110	31.5	7.4	44.2	56%	17.6	56%	17.6	56%	9.0	42.5	54%	17.1	54%	17.2	55%
MAYNOOTH A	220	40	8.5	54.3	54%	20.6	52%	21.2	53%	8.5	47.7	48%	19.2	48%	19.7	49%
POOLBEG	110	40	27.2	43.4	43%	14.5	36%	17.1	43%	21.5	52.0	52%	18.8	47%	20.6	52%
POOLBEG NORT	220	31.5	13.1	63.4	81%	21.8	69%	24.3	77%	6.6	55.2	70%	22.7	72%	22.9	73%
POOLBEG	110	40	27.1	43.3	43%	14.5	36%	17.1	43%	21.4	51.9	52%	18.7	47%	20.6	52%
POOLBEG SOUT	220	31.5	12.2	64.6	82%	22.4	71%	24.5	78%	8.9	65.8	84%	25.7	82%	26.6	84%
SHELLYBANKS	220	40	12.9	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	63.6	64%	21.9	55%	24.4	61%	9.2	70.3	70%	27.2	68%	28.2	71%
SHELLYBANKSB	220	40	13.2	63.6	64%	21.9	55%	24.4	61%	9.2	70.3	70%	27.2	68%	28.2	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	44.2	44%	16.6	41%	17.7	44%	11.2	45.0	45%	17.6	44%	18.7	47%

Appendix 4C – New 400 kV OHL circuit

			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	50%	15.3	61%	28.5	28.9	46%	10.5	42%	12.2	49%
BELCAMP	220	40	12.5	64.3	64%	22.2	55%	24.4	61%	10.0	69.6	70%	26.7	67%	27.9	70%
CARRICKMINES	110	26.2	29.7	36.9	56%	12.4	47%	14.9	57%	23.7	38.4	59%	13.9	53%	15.6	59%
CARRICKMINES	220	40	12.3	59.4	59%	20.8	52%	22.8	57%	8.2	65.1	65%	25.8	64%	26.4	66%
CORDUFF	110	31.5	9.0	60.1	76%	22.3	71%	22.4	71%	10.6	61.8	79%	24.0	76%	24.3	77%
CORDUFF	220	40	14.4	72.1	72%	24.4	61%	27.8	70%	12.3	77.4	77%	29.0	72%	31.4	79%
DUNSTOWN	220	40	8.9	63.8	64%	24.2	60%	25.0	62%	9.2	64.8	65%	25.8	64%	26.6	67%
DUNSTOWN	380	50	5.2	34.0	27%	14.4	29%	14.4	29%	6.3	33.9	27%	14.4	29%	14.5	29%
FIN_URBAN	110	31.5	34.7	41.1	52%	13.7	43%	17.2	54%	30.4	49.5	63%	17.5	56%	20.9	66%
FINGLAS	220	40	15.3	71.1	71%	23.8	60%	27.6	69%	14.1	81.1	81%	29.8	75%	33.3	83%
FIN_RURAL	110	31.5	33.1	41.0	52%	13.2	42%	16.6	53%	27.5	43.0	55%	15.2	48%	17.7	56%
INCH_CITY	110	31.5	28.4	43.0	55%	14.3	46%	17.1	54%	24.6	52.3	66%	18.7	59%	21.2	67%
INCHICORE	220	40	12.1	71.9	72%	24.8	62%	27.1	68%	8.7	78.4	78%	30.5	76%	31.4	79%
INCH_COUNTRY	110	31.5	43.6	43.3	55%	14.0	44%	18.8	60%	32.8	52.6	67%	18.4	59%	22.4	71%
IRISHTOWN	220	40	13.4	67.6	68%	23.2	58%	25.9	65%	10.5	76.7	77%	29.2	73%	30.8	77%
WEST DUBLIN	110	31.5	22.5	49.8	63%	17.1	54%	19.2	61%	23.6	36.3	46%	13.3	42%	14.9	47%
WEST DUBLIN	220	40	9.7	68.2	68%	24.6	62%	25.8	64%	8.5	63.8	64%	25.3	63%	26.0	65%
MAYNOOTH A	110	31.5	10.2	36.9	47%	14.0	45%	14.1	45%	10.9	43.7	56%	17.1	54%	17.3	55%
MAYNOOTH B	220	40	8.5	53.7	54%	20.5	51%	21.1	53%	8.9	42.2	42%	16.9	42%	17.5	44%
MAYNOOTH B	110	31.5	7.6	45.3	57%	17.9	57%	18.0	57%	9.2	43.1	55%	17.3	55%	17.4	55%
MAYNOOTH A	220	40	8.7	62.7	63%	23.6	59%	24.4	61%	8.6	51.6	52%	20.8	52%	21.3	53%
POOLBEG	110	40	27.0	43.6	44%	14.6	37%	17.2	43%	21.3	52.2	52%	18.9	47%	20.7	52%
POOLBEG NORT	220	31.5	13.2	63.0	80%	21.7	69%	24.2	77%	6.6	55.0	70%	22.6	72%	22.8	72%
POOLBEG	110	40	26.9	43.5	43%	14.6	36%	17.1	43%	21.3	52.1	52%	18.8	47%	20.7	52%
POOLBEG SOUT	220	31.5	11.9	65.9	84%	23.0	73%	25.0	79%	8.7	66.7	85%	26.2	83%	27.0	86%
SHELLYBANKS	220	40	12.9	62.8	63%	21.7	54%	24.0	60%	8.1	60.1	60%	23.9	60%	24.4	61%
SHELLYBANKS	220	40	13.0	64.7	65%	22.3	56%	24.8	62%	9.1	71.1	71%	27.7	69%	28.6	72%
SHELLYBANKSB	220	40	13.0	64.7	65%	22.3	56%	24.8	62%	9.1	71.1	71%	27.7	69%	28.6	72%
WOODLAND	220	40	11.3	70.7	71%	25.8	64%	27.6	69%	11.5	69.7	70%	26.9	67%	28.7	72%
WOODLAND	380	40	11.2	43.6	44%	16.4	41%	17.5	44%	11.0	44.5	45%	17.5	44%	18.5	46%

Appendix 4D – New 220 kV OHL circuit

			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	30.825	37.1	59%	12.6218	50%	15.2714	61%	28.5613	28.8996	46%	10.5016	42%	12.2472	49%
BELCAMP	220	40	12.4403	64.5	65%	22.2537	56%	24.4775	61%	9.9574	69.682	70%	26.7547	67%	27.9963	70%
CARRICKMINES	110	26.2	29.1006	36.9	56%	12.3973	47%	14.8531	57%	23.3823	38.3671	59%	13.8943	53%	15.5395	59%
CARRICKMINES	220	40	11.8373	60.0	60%	21.1744	53%	22.9858	57%	8.0422	65.5422	66%	26.0493	65%	26.6204	67%
CORDUFF	110	31.5	9.0008	60.1	76%	22.3678	71%	22.4699	71%	10.6009	61.7684	78%	24.0071	76%	24.2302	77%
CORDUFF	220	40	14.3622	72.3	72%	24.5213	61%	27.9187	70%	12.3393	77.5534	78%	29.042	73%	31.4776	79%
DUNSTOWN	220	40	7.2744	67.2	67%	26.1166	65%	26.5264	66%	7.7357	71.2101	71%	28.961	72%	29.4874	74%
DUNSTOWN	380	50	3.6449	23.5	19%	10.874	22%	10.8762	22%	5.0652	25.3181	20%	11.2645	23%	11.288	23%
FIN_URBAN	110	31.5	34.7096	41.2	52%	13.6672	43%	17.1759	55%	30.4208	49.4914	63%	17.5584	56%	20.9097	66%
FINGLAS	220	40	15.3211	71.3	71%	23.9198	60%	27.7227	69%	14.1102	81.2821	81%	29.8854	75%	33.3197	83%
FIN_RURAL	110	31.5	33.153	41.0	52%	13.2242	42%	16.6008	53%	27.4675	42.9733	55%	15.2219	48%	17.7169	56%
INCH_CITY	110	31.5	27.9339	43.1	55%	14.382	46%	17.0867	54%	24.313	52.3919	67%	18.7528	60%	21.196	67%
INCHICORE	220	40	11.7297	72.4	72%	25.0421	63%	27.2197	68%	8.5863	78.7872	79%	30.7651	77%	31.6404	79%
INCH_COUNTRY	110	31.5	42.7044	43.3	55%	14.0395	45%	18.7601	60%	32.376	52.6815	67%	18.4883	59%	22.4126	71%
IRISHTOWN	220	40	12.9236	68.1	68%	23.4604	59%	26.0141	65%	10.2361	77.1191	77%	29.4634	74%	30.9551	77%
WEST DUBLIN	110	31.5	22.1937	50.0	63%	17.1946	55%	19.2178	61%	23.4052	36.3901	46%	13.3654	42%	14.9092	47%
WEST DUBLIN	220	40	9.4412	68.7	69%	24.8913	62%	25.9989	65%	8.3754	64.1361	64%	25.5551	64%	26.1975	65%
MAYNOOTH A	110	31.5	10.1503	37.1	47%	14.1142	45%	14.2266	45%	10.8902	43.9439	56%	17.1908	55%	17.3685	55%
MAYNOOTH B	220	40	8.2069	54.3	54%	20.8124	52%	21.3397	53%	8.7827	42.5562	43%	17.1469	43%	17.6409	44%
MAYNOOTH B	110	31.5	7.5652	45.4	58%	17.9892	57%	18.0156	57%	9.1816	43.1988	55%	17.3572	55%	17.4326	55%
MAYNOOTH A	220	40	8.5611	63.2	63%	23.8563	60%	24.5742	61%	8.5962	51.8818	52%	20.8885	52%	21.4501	54%
POOLBEG	110	40	26.6733	43.6	44%	14.6562	37%	17.1828	43%	21.1821	52.2076	52%	18.8882	47%	20.721	52%
POOLBEG NORT	220	31.5	13.1903	63.1	80%	21.7529	69%	24.2243	77%	6.6226	55.0104	70%	22.6233	72%	22.838	73%
POOLBEG	110	40	26.6393	43.5	44%	14.6246	37%	17.1398	43%	21.1696	52.1113	52%	18.8543	47%	20.6814	52%
POOLBEG SOUT	220	31.5	11.5833	66.3	84%	23.2114	74%	25.126	80%	8.5975	66.9645	85%	26.3627	84%	27.1041	86%
SHELLYBANKS	220	40	12.8965	62.9	63%	21.7247	54%	24.0691	60%	8.0608	60.1737	60%	23.9217	60%	24.4502	61%
SHELLYBANKS	220	40	12.5633	65.2	65%	22.6034	57%	24.8889	62%	8.8867	71.509	72%	27.8928	70%	28.7828	72%
SHELLYBANKSB	220	40	12.5633	65.2	65%	22.6034	57%	24.8889	62%	8.8867	71.509	72%	27.8928	70%	28.7828	72%
WOODLAND	220	40	11.1551	72.0	72%	26.2557	66%	28.0789	70%	11.5596	70.5813	71%	27.2393	68%	29.0906	73%
WOODLAND	380	40	13.6818	41.2	41%	15.2224	38%	16.8538	42%	13.8622	43.1949	43%	16.5376	41%	18.2372	46%

Appendix 4E – New 220 kV UGC

			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	30.825	37.1	59%	12.6218	50%	15.2714	61%	28.5613	28.8996	46%	10.5016	42%	12.2472	49%
BELCAMP	220	40	12.4403	64.5	65%	22.2537	56%	24.4775	61%	9.9574	69.682	70%	26.7547	67%	27.9963	70%
CARRICKMINES	110	26.2	29.1006	36.9	56%	12.3973	47%	14.8531	57%	23.3823	38.3671	59%	13.8943	53%	15.5395	59%
CARRICKMINES	220	40	11.8373	60.0	60%	21.1744	53%	22.9858	57%	8.0422	65.5422	66%	26.0493	65%	26.6204	67%
CORDUFF	110	31.5	9.0008	60.1	76%	22.3678	71%	22.4699	71%	10.6009	61.7684	78%	24.0071	76%	24.2302	77%
CORDUFF	220	40	14.3622	72.3	72%	24.5213	61%	27.9187	70%	12.3393	77.5534	78%	29.042	73%	31.4776	79%
DUNSTOWN	220	40	7.2744	67.2	67%	26.1166	65%	26.5264	66%	7.7357	71.2101	71%	28.961	72%	29.4874	74%
DUNSTOWN	380	50	3.6449	23.5	19%	10.874	22%	10.8762	22%	5.0652	25.3181	20%	11.2645	23%	11.288	23%
FIN_URBAN	110	31.5	34.7096	41.2	52%	13.6672	43%	17.1759	55%	30.4208	49.4914	63%	17.5584	56%	20.9097	66%
FINGLAS	220	40	15.3211	71.3	71%	23.9198	60%	27.7227	69%	14.1102	81.2821	81%	29.8854	75%	33.3197	83%
FIN_RURAL	110	31.5	33.153	41.0	52%	13.2242	42%	16.6008	53%	27.4675	42.9733	55%	15.2219	48%	17.7169	56%
INCH_CITY	110	31.5	27.9339	43.1	55%	14.382	46%	17.0867	54%	24.313	52.3919	67%	18.7528	60%	21.196	67%
INCHICORE	220	40	11.7297	72.4	72%	25.0421	63%	27.2197	68%	8.5863	78.7872	79%	30.7651	77%	31.6404	79%
INCH_COUNTRY	110	31.5	42.7044	43.3	55%	14.0395	45%	18.7601	60%	32.376	52.6815	67%	18.4883	59%	22.4126	71%
IRISHTOWN	220	40	12.9236	68.1	68%	23.4604	59%	26.0141	65%	10.2361	77.1191	77%	29.4634	74%	30.9551	77%
WEST DUBLIN	110	31.5	22.1937	50.0	63%	17.1946	55%	19.2178	61%	23.4052	36.3901	46%	13.3654	42%	14.9092	47%
WEST DUBLIN	220	40	9.4412	68.7	69%	24.8913	62%	25.9989	65%	8.3754	64.1361	64%	25.5551	64%	26.1975	65%
MAYNOOTH A	110	31.5	10.1503	37.1	47%	14.1142	45%	14.2266	45%	10.8902	43.9439	56%	17.1908	55%	17.3685	55%
MAYNOOTH B	220	40	8.2069	54.3	54%	20.8124	52%	21.3397	53%	8.7827	42.5562	43%	17.1469	43%	17.6409	44%
MAYNOOTH B	110	31.5	7.5652	45.4	58%	17.9892	57%	18.0156	57%	9.1816	43.1988	55%	17.3572	55%	17.4326	55%
MAYNOOTH A	220	40	8.5611	63.2	63%	23.8563	60%	24.5742	61%	8.5962	51.8818	52%	20.8885	52%	21.4501	54%
POOLBEG	110	40	26.6733	43.6	44%	14.6562	37%	17.1828	43%	21.1821	52.2076	52%	18.8882	47%	20.721	52%
POOLBEG NORT	220	31.5	13.1903	63.1	80%	21.7529	69%	24.2243	77%	6.6226	55.0104	70%	22.6233	72%	22.838	73%
POOLBEG	110	40	26.6393	43.5	44%	14.6246	37%	17.1398	43%	21.1696	52.1113	52%	18.8543	47%	20.6814	52%
POOLBEG SOUT	220	31.5	11.5833	66.3	84%	23.2114	74%	25.126	80%	8.5975	66.9645	85%	26.3627	84%	27.1041	86%
SHELLYBANKS	220	40	12.8965	62.9	63%	21.7247	54%	24.0691	60%	8.0608	60.1737	60%	23.9217	60%	24.4502	61%
SHELLYBANKS	220	40	12.5633	65.2	65%	22.6034	57%	24.8889	62%	8.8867	71.509	72%	27.8928	70%	28.7828	72%
SHELLYBANKSB	220	40	12.5633	65.2	65%	22.6034	57%	24.8889	62%	8.8867	71.509	72%	27.8928	70%	28.7828	72%
WOODLAND	220	40	11.1551	72.0	72%	26.2557	66%	28.0789	70%	11.5596	70.5813	71%	27.2393	68%	29.0906	73%
WOODLAND	380	40	13.6818	41.2	41%	15.2224	38%	16.8538	42%	13.8622	43.1949	43%	16.5376	41%	18.2372	46%

Appendix 4F – New 400 kV UGC circuit

			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	30.7	37.1	59%	12.6	50%	15.2	61%	28.5	28.9	46%	10.5	42%	12.2	49%
BELCAMP	220	40	12.4	64.3	64%	22.2	55%	24.4	61%	9.9	69.6	70%	26.7	67%	27.9	70%
CARRICKMINES	110	26.2	30.0	36.9	56%	12.4	47%	14.9	57%	23.8	38.3	58%	13.9	53%	15.6	59%
CARRICKMINES	220	40	12.4	59.8	60%	21.0	52%	23.0	58%	8.3	65.4	65%	25.9	65%	26.5	66%
CORDUFF	110	31.5	9.0	60.1	76%	22.3	71%	22.4	71%	10.6	61.8	78%	24.0	76%	24.2	77%
CORDUFF	220	40	14.3	72.1	72%	24.4	61%	27.8	69%	12.3	77.4	77%	29.0	73%	31.4	79%
DUNSTOWN	220	40	9.4	65.6	66%	24.6	62%	25.6	64%	9.7	66.5	67%	26.3	66%	27.3	68%
DUNSTOWN	380	50	5.6	37.7	30%	15.7	31%	15.7	31%	6.9	38.2	31%	16.0	32%	16.1	32%
FIN_URBAN	110	31.5	34.6	41.1	52%	13.7	43%	17.1	54%	30.3	49.5	63%	17.5	56%	20.9	66%
FINGLAS	220	40	15.2	71.1	71%	23.8	60%	27.6	69%	14.0	81.1	81%	29.8	75%	33.2	83%
FIN_RURAL	110	31.5	33.0	41.0	52%	13.2	42%	16.6	53%	27.4	43.0	55%	15.2	48%	17.7	56%
INCH_CITY	110	31.5	28.5	43.1	55%	14.3	46%	17.1	54%	24.7	52.3	66%	18.7	59%	21.2	67%
INCHICORE	220	40	12.2	72.2	72%	24.8	62%	27.2	68%	8.8	78.6	79%	30.6	76%	31.5	79%
INCH_COUNTRY	110	31.5	43.9	43.3	55%	14.0	44%	18.9	60%	32.9	52.6	67%	18.4	59%	22.5	71%
IRISHTOWN	220	40	13.5	67.9	68%	23.3	58%	26.1	65%	10.5	76.9	77%	29.3	73%	30.9	77%
WEST DUBLIN	110	31.5	22.7	49.9	63%	17.1	54%	19.2	61%	23.7	36.4	46%	13.3	42%	14.9	47%
WEST DUBLIN	220	40	9.8	68.4	68%	24.7	62%	25.9	65%	8.5	64.0	64%	25.4	64%	26.1	65%
MAYNOOTH A	110	31.5	10.2	37.1	47%	14.1	45%	14.2	45%	11.0	43.9	56%	17.1	54%	17.3	55%
MAYNOOTH B	220	40	8.6	54.0	54%	20.5	51%	21.2	53%	9.0	42.4	42%	17.0	43%	17.6	44%
MAYNOOTH B	110	31.5	7.6	45.4	58%	18.0	57%	18.0	57%	9.2	43.2	55%	17.3	55%	17.4	55%
MAYNOOTH A	220	40	8.7	62.9	63%	23.7	59%	24.4	61%	8.7	51.8	52%	20.8	52%	21.4	53%
POOLBEG	110	40	27.1	43.6	44%	14.6	37%	17.2	43%	21.4	52.2	52%	18.9	47%	20.7	52%
POOLBEG NORT	220	31.5	13.1	63.0	80%	21.7	69%	24.1	77%	6.6	54.9	70%	22.6	72%	22.8	72%
POOLBEG	110	40	27.1	43.5	43%	14.6	36%	17.2	43%	21.4	52.1	52%	18.8	47%	20.7	52%
POOLBEG SOUT	220	31.5	12.0	66.2	84%	23.0	73%	25.1	80%	8.7	66.8	85%	26.2	83%	27.0	86%
SHELLYBANKS	220	40	12.8	62.8	63%	21.7	54%	24.0	60%	8.0	60.1	60%	23.9	60%	24.4	61%
SHELLYBANKS	220	40	13.1	65.0	65%	22.4	56%	24.9	62%	9.1	71.4	71%	27.7	69%	28.7	72%
SHELLYBANKSB	220	40	13.1	65.0	65%	22.4	56%	24.9	62%	9.1	71.4	71%	27.7	69%	28.7	72%
WOODLAND	220	40	11.1	71.1	71%	25.9	65%	27.7	69%	11.5	70.4	70%	27.2	68%	29.0	72%
WOODLAND	380	40	9.5	44.9	45%	17.1	43%	17.8	44%	10.2	46.7	47%	18.4	46%	19.3	48%

Appendix 4G – Summary of general short circuit level trends observed at main buses

The following table gives the short circuit levels at a number of buses for the various options. These values are expressed as a percentage of the lowest rated short circuit value of equipment in the station. A large red arrow beside a table row indicates that the short circuit levels increased on all indicated buses in relation to the base case. For the row related to the up-voltage option the small black downward arrows indicate that short circuit levels decreased on those buses, and similarly the small red upward arrow indicates the short circuit levels increased in relation to the base case.

Bus	Inchicore	Maynooth A 220	Maynooth B 220	Dunstown 220	Dunstown 380	Woodland 220	Woodland 380	
Base case	71%	62%	53%	57%	18%	69%	36%	
Upvoltage existing circuits to 400 kV	70% ↓	54% ↓	47% ↓	55% ↓	26% ↑	75% ↑	44% ↑	
New Dunstown-Woodland 400 kV OHL	72%	63%	54%	64%	27%	71%	44%	} ↑
New Dunstown-Woodland 220 kV OHL	72%	63%	54%	67%	19%	72%	41%	} ↑
New Dunstown-Woodland 220 kV UGC & Split Woodland	72%	63%	54%	67%	19%	72%	41%	} ↑
New Dunstown-Woodland 400 kV UGC	72%	63%	54%	66%	30%	71%	45%	} ↑