East Coast Generation Opportunity Assessment

February 2019

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1. Executive Summary

There has been a recent upsurge in interest in off-shore wind generation. There is already a small windfarm off the East coast at Arklow in County Wicklow and a grid connection offer has been issued to a larger windfarm developer off the north east coast. There are also connection applications for a further 1,200 megawatts (MW) of offshore wind along the East coast.

It is now likely that offshore wind generation will play a key part in meeting Ireland's 2030 climate change targets. This is addressed in our Tomorrow's Energy Scenarios research, which assesses the impact of connecting up to 3,010 MW of offshore generation.

The development of off-shore wind is also expected to be addressed in the new All-of-Government Plan to make Ireland a leader in responding to climate change, to be published later this year.

We in EirGrid are continuing to investigate delivery models for planning and enabling the development and connection of off-shore wind generation to the Irish transmission system. This investigation includes consideration of the approaches adopted in other jurisdictions, including a centralised model coordinated by EirGrid.

It is expected that the initial phases of offshore wind generation development in Ireland will be focused on the East coast of the country.

In tandem with the development of offshore wind generation, we have also had numerous enquiries about the connection of large, conventional thermal generation projects in and around Dublin. Electricity demand is increasing rapidly in the greater Dublin region primarily due to the growth of data centres which require large amounts of power. It is likely that both offshore wind and new thermal generation will be required to meet the growing electricity demands in the eastern region.

This report presents analysis that EirGrid has undertaken to identify the opportunities for connecting new power generation sources in the East coast region of Ireland from a grid capacity perspective. The analysis provides useful information for developers seeking to connect generation in the region.

This East Coast Generation Assessment considers a range of locations with strong 220 kV electrical connectivity to the Dublin region. The locations considered are strong points on the grid: Carrickmines and Arklow in the South Dublin/Wicklow area, Louth and Woodland in the Meath/Louth area and Poolbeg and Finglas in the Dublin City area. Offshore wind generation capacities up to 800 MW and conventional thermal generation of 450 MW were tested at each location.

All areas were shown to have considerable capacity available for new offshore wind generation. Where the available capacity can be further improved by potential reinforcements, these options are presented and discussed within the report. Additionally, details of the physical space available at existing substations are provided. This will facilitate potential developers to assess potential connection options in the study areas.

The results indicate that locations close to the Dublin load centre and/or with multiple 220 kV connections into the Dublin area have the best opportunities for new generation capacity. Arklow and Louth locations have less opportunities available than the other locations because they have less (typically only one) 220 kV transmission connections to Dublin.

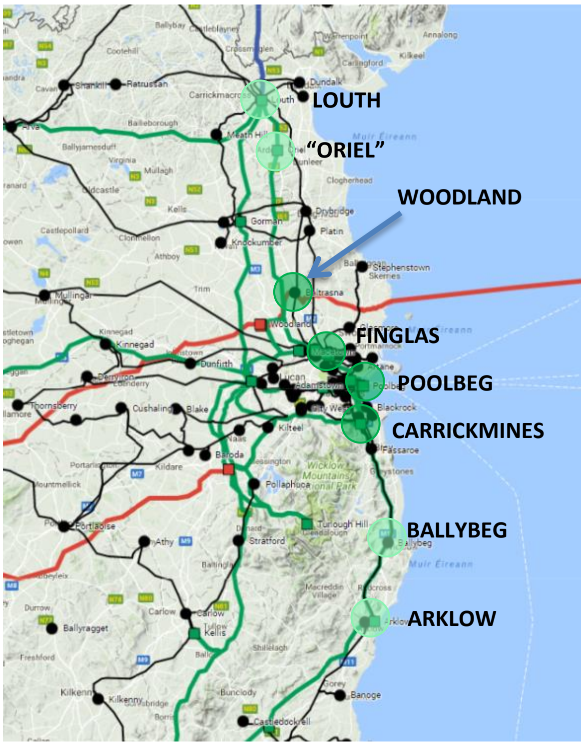

Figure 1-1: Overview of the locations considered

Table 1-1: Summary of Opportunity Results for Offshore Wind Generation

Substation	Opportunity for Offshore Wind Before significant works (MW)	Space at Substation
Louth	450	4 x bay space
Oriel (New 220kV substation)	400	New Substation
Woodland	>800	2 x bay space
Poolbeg North	600	2 x bays
Poolbeg South	>800	2 x bays
Finglas	>800	1x bays
Carrickmines	650	3 x bays
Ballybeg (New 220kV substation)	500	New Substation
Arklow	350	2 x bay Space

Poolbeg and Finglas have capacity available for a 450 MW high-merit conventional thermal generator. The other locations considered would need some level of system reinforcements in order to secure the capacity for a 450 MW high-merit conventional thermal generator.

Potential developers who are considering new generator connections and wish to discuss the content of this document are encouraged to contact us. This report is intended to provide indicative opportunity information to potential new developers of power sources in the Dublin area and should be considered in parallel with the EirGrid Tomorrow's Energy Scenarios publications[1], the All Island Generation Adequacy Statement[2] and the All Island Ten Year Transmission Forecast Statement[3]. Any developer looking to progress a project will have to apply through the appropriate channels and will be processed through the Connection Offer Process[4]. The content of this report should not be taken to prejudge the outcome of the official Offer Process.

The transmission capacity information provided in this report is based on power flow studies. Should a developer apply for a connection, additional detailed studies may be required, such as; short circuit analysis, stability studies and power quality studies.

[1] http://www.eirgridgroup.com/customer-and-industry/energy-future/
[2] http://www.eirgridgroup.com/site-files/library/EirGrid/Generation_Capacity_Statement_2018.pdf
[3] http://www.eirgridgroup.com/site-files/library/EirGrid/TYTFS-2017-Final.pdf
[4] Applications for generation are currently being processed per Enduring Connection Policy (ECP-1)

2. Context

2.1. Context of East Coast Generation Opportunities Report

Dublin and the surrounding areas are experiencing a rapid increase in the level of customers signing contracts for new demand connections. This rapid increase in demand will lead to a need for more generation power sources. Renewable generation will help meet ongoing emissions targets while additional conventional thermal generation will be required to meet demand when renewable generation is unavailable.

Developing new power sources in locations remote from the Dublin load centre will require transmission reinforcement to facilitate the power flows into the region. The lead-times associated with transmission reinforcement could cause delays for both demand customers and new generators. A complementary approach would be to locate the new power sources close to the growing demand. Such an approach would minimise the requirements to reinforce the network from other regions into the Dublin area (but would not necessarily remove the requirement to reinforce the network within the Dublin area).

Developers have been considering both offshore wind and conventional generation projects along the eastern seaboard. Therefore, this report is focused on opportunities for large scale offshore wind and conventional generation development potential. Other types and forms of generation will naturally form part of the generation mix in the Dublin Region in the future. The information in this report will also be informative for those forms of generation.

This East Coast Generation Assessment considers a range of locations with strong 220 kV electrical connectivity to the Dublin region and provides a suite of qualitative analysis to describe the capacity opportunities for new generation at these locations. The locations considered are on or near the east coast of Ireland, see Table 2-1.

Table 2-1: 220kV Nodes Studied

Area	**220kV Node**
South Dublin and Wicklow area	• Carrickmines • Ballybeg • Arklow
Meath and Louth area	• Louth • Oriel • Woodland
Dublin City area	• Poolbeg • Finglas

Where potential system reinforcements could improve the available capacity, these options are presented. Finally, details of the physical space available at existing substations are provided. This will facilitate potential developers to assess potential connection options in the study areas.

2.2. In Context of other EirGrid publications

The information in this East Coast Generation Assessment should be considered in parallel with information provided in other EirGrid publications.

The Tomorrow's Energy Scenario reports set out a number of potential future environments for grid operations and outline the likely reinforcements required to meet the future needs. The Tomorrow's Energy Scenario 2017 Needs Assessment shows a high need for grid development into the Dublin region from other regions to meet the growing demand in Dublin and surrounding counties.

The All Island Generation Capacity Statement sets out the forecasts for demand for the following 10 years, and the projections of generation capacity adequacy to meet those demands. The 2018 statement indicates the potential for significant generation capacity deficits beyond 2024. Future capacity auctions are likely therefore to require increased capacity volume. This report provides useful information for those developers planning to participate in future auctions who are seeking to locate new capacity along the eastern coast.

The All Island Ten Year Transmission Forecast Statement (TYTFS) provides detailed network, demand and generation information for the following 10 years. It also provides information of opportunities for new generation and demand projects. However, it should be noted that the East Coast Generation Assessment methodology is different and more bespoke than the standard Ten Year Transmission Forecast Statement opportunity analysis. A comparison of the two approaches is provided in Section 3.3.2 below.

3. Methodology and Assumptions

3.1. Methodology Overview

The analysis was completed by testing a connection of 800 MW of offshore wind generation at each of the study locations in turn. Separately, a conventional thermal generator with a capacity of 450 MW was also tested at each location. This value is typical of the largest sized units currently connected to the Irish system. These 'Test Capacity' figures were assumed based on EirGrid's understanding of the types of connections that developers are considering.

In order to restore the supply-demand balance in the basecase following the inclusion of the test capacity in the network model, other generation sources were dispatched down by the same amount.

The impact of the new generation on the transmission network was tested using load flow simulation software. The analysis was attempting to identify if the new connections resulted in the transmission system going outside of standards[5]. In particular, the analysis considered if transmission equipment would become overloaded as a result of the power flows coming from the new generation. This analysis was conducted under intact network conditions (all transmission circuits available) and contingency scenarios where one item of transmission equipment becomes unavailable.

Where a network limitation was identified in any of the analyses, the test capacity was reduced until the network limitation was resolved.

Contingency outages at times of transmission maintenance outages were not taken into account. While maintenance outages may result in additional network constraints, they are time limited. Results for these conditions would not reflect normal operation.

Unless specifically stated otherwise, the analysis for each location was conducted on an individual basis. As such, the opportunities presented are not cumulative. If a new generator connects in the east coast, this will use up some or all of the capacity available at other locations in the east coast.

While the analysis in this document focuses on the available transmission capacity, there may be other technical limitations that restrict the amount of generation that can be connected. This could include factors like system stability considerations, short circuit limitations[6] and factors associated with the loss of a very large single infeed of generation. These studies are complex and require accurate data from the connecting party, and are therefore normally done after offer acceptance.

3.2. Study Year

The chosen study year is 2025. This year was considered indicative of a future scenario where there has been significant load growth in the Dublin area.

The analysis was based on the data compiled for the 2017 All Island Ten Year Transmission Forecast Statement. Contracted positions of generation and demand customers were updated to account for

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[5] http://www.eirgridgroup.com/site-files/library/EirGrid/EirGrid-Transmission-System-Security-and-Planning-Standards-TSSPS-Final-May-2016-APPROVED.pdf

[6] It should be noted that there are a number of areas within the Dublin network which could be susceptible to high fault levels. New generator connections could further increase fault levels and require mitigation solutions to be developed. Potential developers should consult the short circuit information in the TYTFS in order to be aware of the high fault level areas: http://www.eirgridgroup.com/site-files/library/EirGrid/TYTFS-2017-Final.pdf

changes since the data was compiled for that statement. In particular, there has been a large interest in data centre demand connections in the Dublin area within the last year. To take account in this study of this new data, the total data centre load in the region was increased to approximately 1,100 MVA. This represents the large number of data centers that have signed contracts at the time of this study.

Major reinforcement projects such as the North-South Interconnector, the Regional Solution[7], and Capital Project 966 were assessed in order to determine if they were specifically required to facilitate the new generation at each of the locations considered.

3.3. Dispatch Assumptions

3.3.1. Merit Order and Renewable Prioritisation

The SEM-11-062, 'SEM Committee Decision Paper – Principles of Dispatch and the Design of the Market Schedule in the Trading and Settlement Code' requires the prioritisation of wind generation in dispatch. This prioritisation continues to apply into the new wholesale electricity market arrangements SEM (Single Electricity Market).

As wind is a priority classification generation type, it is assumed that it can be dispatched on, ahead of conventional thermal generation. This assumption is a key component of the analysis contained within this document. The analysis focused on scenarios when the wind output is at 100% of the maximum export capacity.

To restore the supply-demand balance in the basecase, the approach in this analysis is to dispatch down the most expensive generation in the merit order. In the case of testing for opportunities for wind generation, where network issues are identified, reconfiguration of the existing thermal generation in the Dublin area is examined as a short term mitigation measure. This is consistent with priority dispatch rules. It may increase dispatch balancing costs and would therefore require consideration from an overall renewable integration and network development policy context.

When assessing the connection of a new conventional thermal plant it is assumed that the new unit will be very high in the merit order. The connection is then assessed against credible dispatch scenarios, where the new generation unit displaces the most expensive generation in the base case dispatch. Specifically, it is assumed that other high merit order Dublin generation will be generating at the same time as the new unit. It is assumed that lower merit order Dublin units (e.g. open cycle combustion turbines) will not be dispatched.

3.3.2. Comparison with All Island Ten Year Transmission Forecast Statement

The East Coast Generation Assessment methodology is different and more bespoke than the standard Ten Year Transmission Forecast Statement opportunity analysis.

Both the Ten Year Transmission Forecast Statement and this analysis examine opportunity for new generation by adding the new generation in the network model and dispatching down other generation sources in the base case by the same amount.

[7] This project includes reinforcements and upgrades in the south east and Munster regions. Further details can be found in the Transmission Development Plan: http://www.eirgridgroup.com/site-files/library/EirGrid/TDP_2017_Final_for_Publication.pdf

The Ten Year Transmission Forecast Statement approach is to test a number of dispatch-down scenarios (see TYTFS 2017 Section 6.2) to identify a minimum level of available transmission capacity.

This is different to the approach taken in the analysis for this report and described in Section 3.3.1 above.

3.3.3. Firmness of Connection

Despite this priority dispatch assumption, this analysis should not be considered as an assessment of the firm access available on the transmission network. The most recent connection policy indicates that future connections are likely to be on a non-firm basis. Non-firm generators are not reimbursed during periods when the generator is constrained back from its market position. Non-firm generators are also unlikely to have deep reinforcements associated with their connection.

The analysis in this report could be considered as an indication of the capacity available in the local or directly adjacent transmission network. This is often referred to as the shallow capacity. Despite having shallow capacity available, generators may be susceptible to having their output reduced due to dispatch patterns on the wider transmission system (for example in a scenario where large power flows are coming from wind generation in other parts of the country).

Where shallow capacity is limited, the analysis will attempt to describe any key enabling works that could be implemented in order to increase the shallow capacity available for a new connection. In addition to these works, further system reinforcement works may be required if firm capacity is to be provided to new power sources.

3.3.4. Transmission Constraints

EirGrid has defined a number of Transmission Constraint Groups (TCGs[8]). These are required to ensure system stability, prevent equipment overloading and maintain voltages within limits. Some of the TCGs are specific to maintaining a defined level of generation within the Dublin region. Throughout this analysis, if a generation re-dispatch is required, it is assumed that the TCG limitations will be respected.

3.4. Network Configuration

The Dublin transmission network can be sectionalised into separate north and south rings. This is typically done in order to prevent high fault levels and to reduce excessive power flows through the Dublin network. The sectionalising is implemented through operational arrangements and network devices. Generation at Poolbeg can be configured to supply north or south Dublin as necessary. The Carrickmines-Poolbeg circuit also has a phase shifting transformer (PST) which can be used to control power flows on the circuit. Throughout this analysis the Dublin sectionalising arrangements and PST settings were configured to optimise the capacity available at the location being studied.

3.5. Reinforcement Assumptions

This report does not address costs, deliverability or environmental aspects of any potential connections or reinforcements. Any additional reinforcements identified in this report are indicative and are

8 http://www.eirgridgroup.com/site-files/library/EirGrid/OperationalConstraintsUpdateVersion1_48_January_2017.pdf

presented for information only; they have not been developed through EirGrid's six step approach to developing grid infrastructure projects[9]. If a large scale power producer was to progress to signing a connection offer, any resultant network solutions would have to progress through the appropriate steps of need identification, solution optioneering, consultation etc.

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

4. South Dublin and Wicklow Area Opportunities

This study area can be described as the area between Arklow and Carrickmines 220 kV substations (see Figure 4-1). Connections in this area could be directly into either Arklow or Carrickmines substations, or through a new 220 kV substation which could be “looped” into the existing Arklow-Carrickmines 220 kV circuit.

Carrickmines is a 220/110 kV bulk supply point (BSP) in the south of the city. The substation has four 220 kV circuits and four 220/110 kV transformers. The power flow on the circuit between Carrickmines and Poolbeg can be controlled by a Phase Shifting Transformer.

Arklow is a 220/110 kV substation in south Co. Wicklow. The substation has two 220 kV circuits and two 220/110 kV transformers.

Ballybeg is currently a 110/MV distribution substation. This study examined the capacity potential for a new 220/110 kV substation at the site. The substation would be connected to four 220 kV circuits, and would have two 220/110kV transformers (see Section 4.3.1 for details).

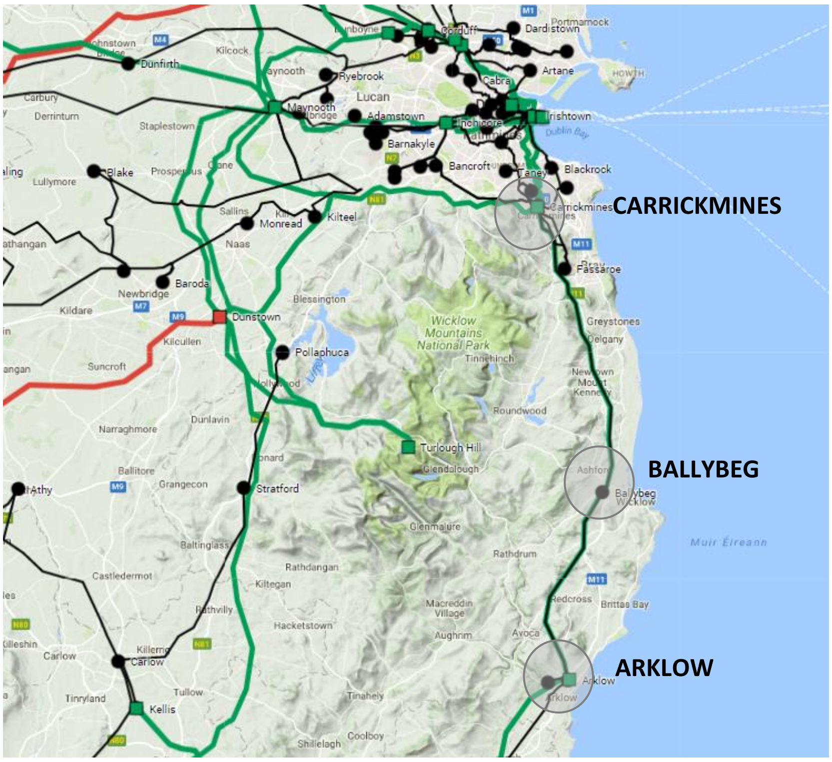

Figure 4-1: Geographical and Electrical Representation of the South Dublin and Wicklow Area

4.1. Summary of Opportunities for new Offshore Wind Generation

The results are summarised in the following table. Please see the subsequent sections for specific details of the limitations and potential mitigations.

Table 4-1: Summary of South Dublin and Wicklow Area Offshore Opportunities

Location	Offshore Capacity (MW)	Network Conditions or Assumed Reinforcement	Substation Space
Carrickmines	650	Base Case	3 x bays
	350	350 MW new offshore assumed connected at Arklow	
	800	New Carrickmines-Poolbeg circuit	
Ballybeg	500	Upvoltage Ballybeg-Carrickmines	New Substation
	700	Upvoltage and uprate circuits to Carrickmines	
Arklow	350	Base Case (Ballybeg bay conductors uprated)	2 x bay Space
	500	Upvoltage Arklow-Ballybeg-Carrickmines	
	800	Upvoltage and uprate Arklow-Ballybeg-Carrickmines	

4.2. Carrickmines Opportunities

4.2.1. Existing Network

A maximum of 650 MW of offshore wind can be connected at Carrickmines while keeping the network within standards.

The initial assessment considered the impact of 800 MW of offshore wind at Carrickmines 220 kV busbar during standard merit order dispatch of conventional generation. The analysis indicated that 800 MW caused overloads in the intact network (where all transmission circuits are available) on Inchicore-Irishtown and Carrickmines-Irishtown 220 kV circuits. Circuit overloads are exacerbated if critical 220 kV circuits in the area are out of service.

Further analysis identified that the overloads can be partially mitigated if conventional thermal generation in the Dublin area was reconfigured (see Section 3.3.1). With this mitigation in place the analysis indicated a maximum of 650 MW of offshore wind can be connected at Carrickmines.

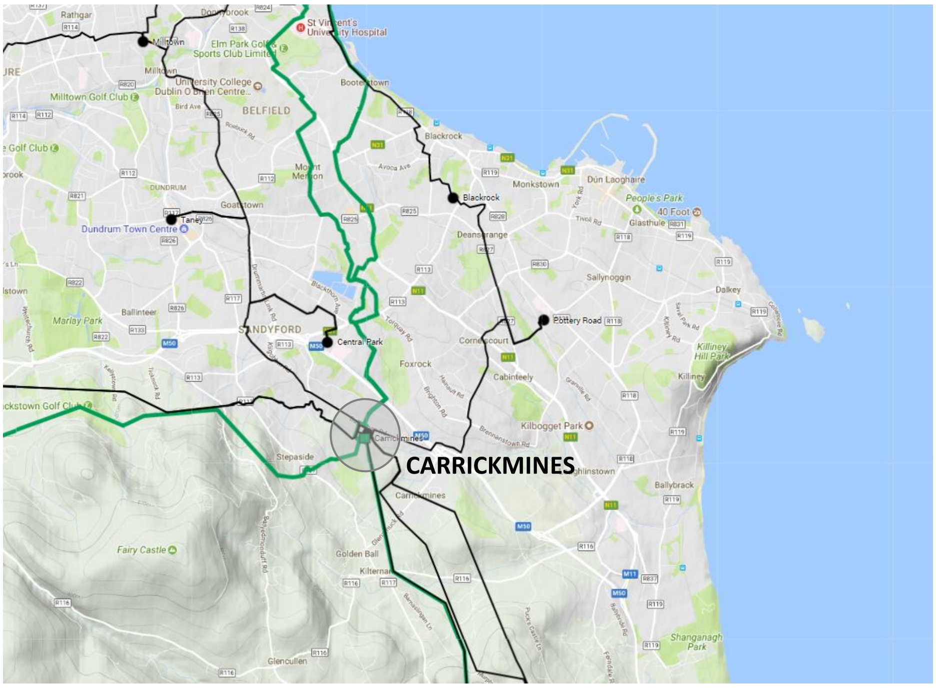

Figure 4-2: Geographical and Electrical Representation of the Carrickmines 220 kV Substation

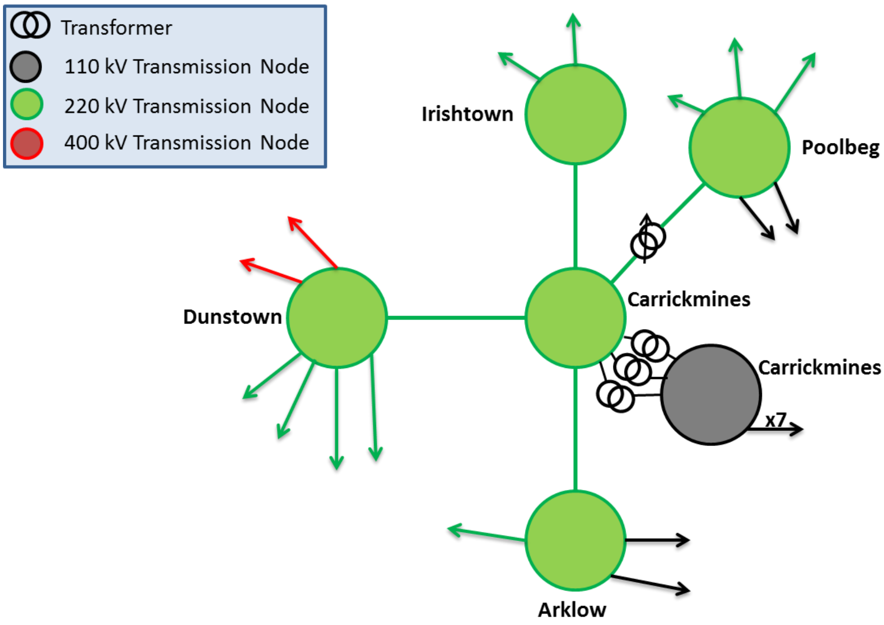

Figure 4-3: Node Diagram of the Carrickmines 220 kV substation in the south of Dublin city

4.2.2. Network Solutions

In order to connect the full 800 MW of offshore wind at Carrickmines, a solution would be required to facilitate increased power flows out of Carrickmines. This could include, for example, a new Carrickmines to Poolbeg 220 kV cable which would provide another path for power flows from Carrickmines into the Dublin load centre.

4.2.3. Connection Options

This section describes the options that exist for grid connections into the existing Carrickmines substation or loop-in connections to existing circuits in the study area.

The Carrickmines 220 kV substation is located approximately 6 km from the coast (see Figure 4-2). An initial desktop assessment has indicated that there is physical space for three additional 220 kV bays in the substation.

Carrickmines 220 kV busbar is in the process of being transitioned from an older 220 kV Air Insulated Switchgear (AIS) busbar to a new GIS busbar. This new busbar creates options for new connections. Detailed site investigation would be required to confirm the final amount of available bays and the status of the equipment in these bays.

4.3. Ballybeg Opportunities

4.3.1. Existing Network

The Arklow-Carrickmines 220 kV circuit is actually part of a double-circuit transmission corridor (two circuits on the one set of towers). The other part of the circuit is built to 220 kV transmission standards (summer/winter rating of 434/534 MVA) but is operated at 110 kV and forms the Arklow-Ballybeg-Carrickmines circuit. This circuit is therefore limited to summer/winter rating of 136/166 MVA. This limitation is imposed by the 110 kV equipment used at each of the substations.

A new Ballybeg 220 kV substation could be “looped” into the existing Arklow-Carrickmines 220 kV circuit. At which point the other side of the double circuit could also be changed from 110 kV operation to 220 kV operation (see Figure 4-5). The existing Ballybeg 110kV substation is located approximately 3.3 km from the coast (see Figure 4-1).

With this connection arrangement, it was found that a maximum 500 MW of offshore wind could be accommodated at Ballybeg. Beyond 500 MW, overloads would occur on Ballybeg-Carrickmines 220 kV circuit no.1 for the loss of the Ballybeg-Carrickmines 220 kV circuit no.2 and vice-versa. Although this arrangement results in four 220 kV circuits into Ballybeg, the predominant power flow direction would be north towards Dublin and so the loss of one of the “north” circuits would result in an overload of the remaining “north” circuit.

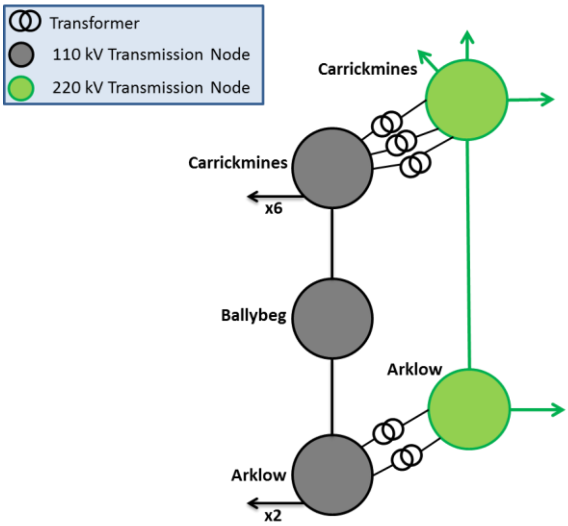

Figure 4-4: Node Diagram of the existing Ballybeg 110 kV substation in Wicklow

4.3.2. Network Solutions

Further improvements in capacity could be achieved by increasing the rating of the 220 kV conductors. This would involve replacing the existing conductors with new higher capacity conductors but utilising the existing towers. Based on ESB Networks standards, the maximum summer/winter rating achievable for a 220 kV conductor is 761/794 MVA. With two 220 kV transmission circuits of maximum rating, it was found that 700 MW of offshore wind could be accommodated at Ballybeg.

Beyond 700 MW, issues were encountered on the circuits north of Carrickmines. Overloads can occur in the intact network (where all transmission circuits are available) on Inchicore-Irishtown and Carrickmines-Irishtown 220 kV circuits under various dispatch conditions and system configurations. Circuit overloads are exacerbated if critical 220 kV circuits in the area are out of service. These are similar to the issues described in Section 4.2.1. Network solutions similar to those described for Carrickmines (see Section 4.2.2) would be required to ensure 800 MW of offshore wind could be accommodated at Ballybeg.

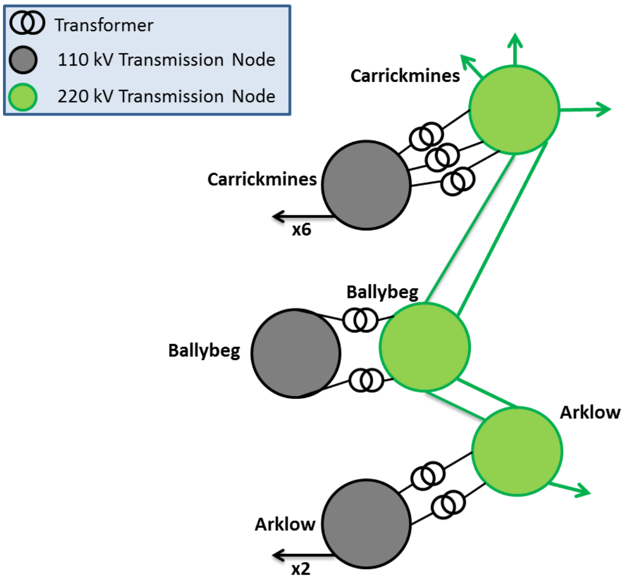

Figure 4-5: Illustration of a potential new Ballybeg 220 kV substation

4.4. Arklow Opportunities

4.4.1. Existing Network

The analysis indicates that a maximum of 350 MW of offshore wind can be connected at Arklow before overloads become a problem. This analysis assumes that the bay conductors at Ballybeg substation are uprated, such that they are not the limiting element.

The initial assessment considered the impact of 800 MW of offshore wind at Arklow 220 kV busbar during standard merit order dispatch of conventional generation. The analysis indicated that 800 MW caused overloads in the intact network (where all transmission circuits are available) on Arklow-Carrickmines, Inchicore-Irishtown and Carrickmines-Irishtown 220 kV circuits.

Circuit overloads are exacerbated if critical 220 kV circuits in the area are out of service. For example, for the loss of Arklow-Carrickmines 220 kV circuit, overloading occurs on the Arklow-Ballybeg and Ballybeg-Carrickmines 110 kV circuits, Arklow-Lodgewood and Great Island-Lodgewood 220 kV circuits and the two Arklow 220/110 kV transformers, T2101 and T2102.

As a result of this limitation, the analysis indicated a maximum of 350 MW of offshore wind can be connected at Arklow with the existing network.

Figure 4-6: Geographical and Electrical Representation of the Arklow 220 kV Substation

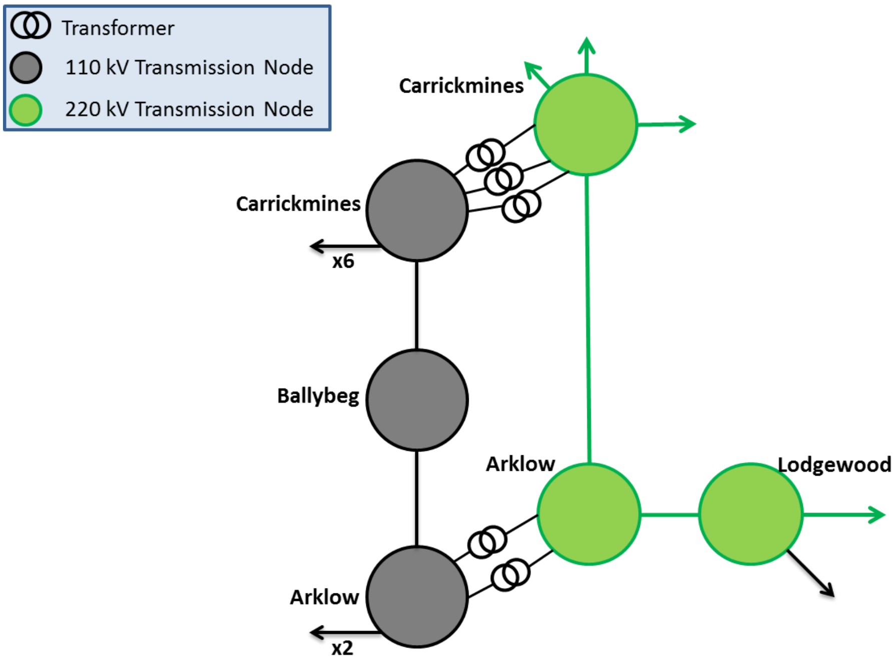

Figure 4-7: Node Diagram of the Arklow 220 kV substation

4.4.2. Network Solutions

As described in Section 4.3, converting the Arklow-Ballybeg-Carrickmines circuit from 110 kV operation to 220 kV operation would improve the capability of the network in the area by providing two 220 kV transmission circuits to facilitate northerly power flows out of the area towards Dublin. With this network reconfiguration, it was found that 500 MW of offshore wind could be accommodated at Arklow. Beyond 500 MW, overloads would occur on one of the 220 kV circuits between Arklow and Carrickmines for the loss of the other circuit.

In order to facilitate the connection of the full 800 MW of offshore wind the rating of the two Arklow-Carrickmines 220 kV circuits must be increased to 761/794 MVA[10]. With two 220 kV transmission circuits of maximum rating, it was found that 800 MW of offshore wind could be accommodated at Arklow. While not specifically identified in this analysis, further reinforcements to increase network capacity between Carrickmines and Dublin would improve the capability of generation at Arklow to service the Dublin load centers.

It should be noted that connecting 800 MW at Arklow would require much further detailed analysis. While this is true for all the other locations described in this report, Arklow, in particular, appeared to be susceptible to system issues in the event of a loss of the double circuit to Carrickmines. Detailed stability analysis would be required to ensure that these issues can be managed.

4.4.3. Connection Options at Arklow

The Arklow 220 kV substation is located approximately 1.5 km from the coast (see Figure 4-6). An initial assessment has indicated that there could be physical space for two additional 220 kV bays in the substation. However, it should be noted that the Arklow 220 kV busbar is an older form of 220 kV Gas Insulated Switchgear (GIS). There are no spare, equipped 220 kV bays. A detailed site and technical

[10] 761/794MVA represent the maximum standard summer and winter ratings respectively for 220 kV overhead lines in Ireland

investigation would be required to confirm if it is possible to accommodate additional 220 kV bays. Also, as described in Section 4.3.2, depending on the quantity of new generation that connects in this area, it may be necessary to revert the Arklow-Ballybeg-Carrickmines to 220 kV operation. This will require a 220 kV bay in Arklow.

4.5. Carrickmines and Arklow Combined Opportunities

As described in Section 3.1 the capacity opportunity information presented in this report are not cumulative. However, in some locations it was considered that there was merit in assessing the cumulative capacity available at multiple locations. In this case, the analysis considered how much offshore wind could be accommodated simultaneously at both Arklow and Carrickmines without additional system reinforcements.

It was found that a total of 700 MW could be connected collectively at Carrickmines and Arklow. This was composed of 350 MW at Carrickmines and 350 MW at Arklow [11]. As noted in Section 4.4.1, this analysis also assumes that the bay conductors at Ballybeg substation are uprated, such that they are not the limiting element.

Above 700MW, transmission limits were identified between Arklow and Carrickmines similar to those described in Section 4.4.1; these relate to overloads in the event of a loss of the Arklow-Carrickmines 220 kV circuit. These issues are largely specific to the connection of offshore wind at Arklow. In addition, transmission limits were identified between Carrickmines and the centre of Dublin similar to those described in Section 4.2.1; these relate to overloads on the 220 kV circuits around south Dublin. In this case, the issues are caused by the cumulate power flows from the offshore wind at both Arklow and Carrickmines.

4.6. Opportunities for new Conventional Generation

The assessment considered the impact of a 450 MW high-merit conventional thermal generation unit at Arklow or Ballybeg during standard merit order dispatch of other conventional generation.

The analysis indicated overloads on the existing network between Arklow and Carrickmines and also on the circuits between Carrickmines and the rest of the Dublin network. These overload issues are directly linked to the dispatch assumptions in the analysis. Unlike for priority dispatch wind, it is assumed that these overloads cannot be mitigated by reconfiguration of the conventional thermal generation in the Dublin area.

The results indicate that reinforcements similar to those described in Section 4.3.2 would be required. These could include:

- Converting the Arklow-Ballybeg-Carrickmines circuit from 110 kV operation to 220 kV operation;
- Increased capacity for power flows out of Carrickmines, for example, by creating a new link between Carrickmines and Poolbeg 220 kV substations.

[11] This ratio is largely dictated by the initial limitation of the Arklow capacity as described in Section 4.4.1

Connecting a 450 MW high-merit conventional thermal generator at Carrickmines does not cause issues on the Arklow-Carrickmines circuits; however, it does impact on the circuits between Carrickmines and the rest of the Dublin network.

The results indicate that reinforcement similar to what was described in Section 4.2.2 would be required:

- Increased capacity for power flows out of Carrickmines, for example, by creating a new link between Carrickmines and Poolbeg 220 kV substations.

6. Meath and Louth Area Opportunities

This study area can be described as the area between Woodland and Louth 220 kV substations (see Figure 6-1). Connections could be directly into either Louth or Woodland substations. Alternatively a connection could be into a new 220 kV substation.

Louth is a 220/110 kV substation near Dundalk. The substation is connected by three 220 kV circuits, two 275 kV circuits to Northern Ireland and has four 220/110 kV transformers.

Woodland is a 400/220 kV substation in Co. Meath. The substation is connected by one 400 kV circuit, one 500 MW HVDC interconnector, four 220 kV circuits and has three 400/220 kV transformers.

Oriel is a potentially new 220kV substation in the north east of Ireland. It could be "looped" into the existing Louth-Woodland 220 kV circuit, such as the connection method for the Oriel wind farm which has a Gate 3 connection offer to connect into this circuit. The Louth-Woodland 220kV circuit has a summer/winter rating of 434/534 MVA, assuming that the bay conductor at Louth has been uprated.

6.1. Summary of Opportunities for new Offshore Wind Generation

The results are summarised in the following table. Please see the subsequent sections for specific details of the limitations and potential mitigations.

Table 6-1: Summary of Meath and Louth Area Offshore Opportunities

Location	Offshore Capacity (MW)	Network Conditions or Assumed Reinforcement	Substation Space
Louth	450	Base Case	4xbay space
	650	North South, CP966, uprate Louth - Woodland 220kV circuit	
	800	As above & Sliabh Bawn-Lanesboro and Lanesboro busbar uprated	
Oriel	400	Base Case	New Substation
	650	North South, CP966, uprate Louth - Woodland 220kV circuit	
	800	As above & Sliabh Bawn-Lanesboro and Lanesboro busbar uprated	
Woodland	800	Base Case	2xbay space

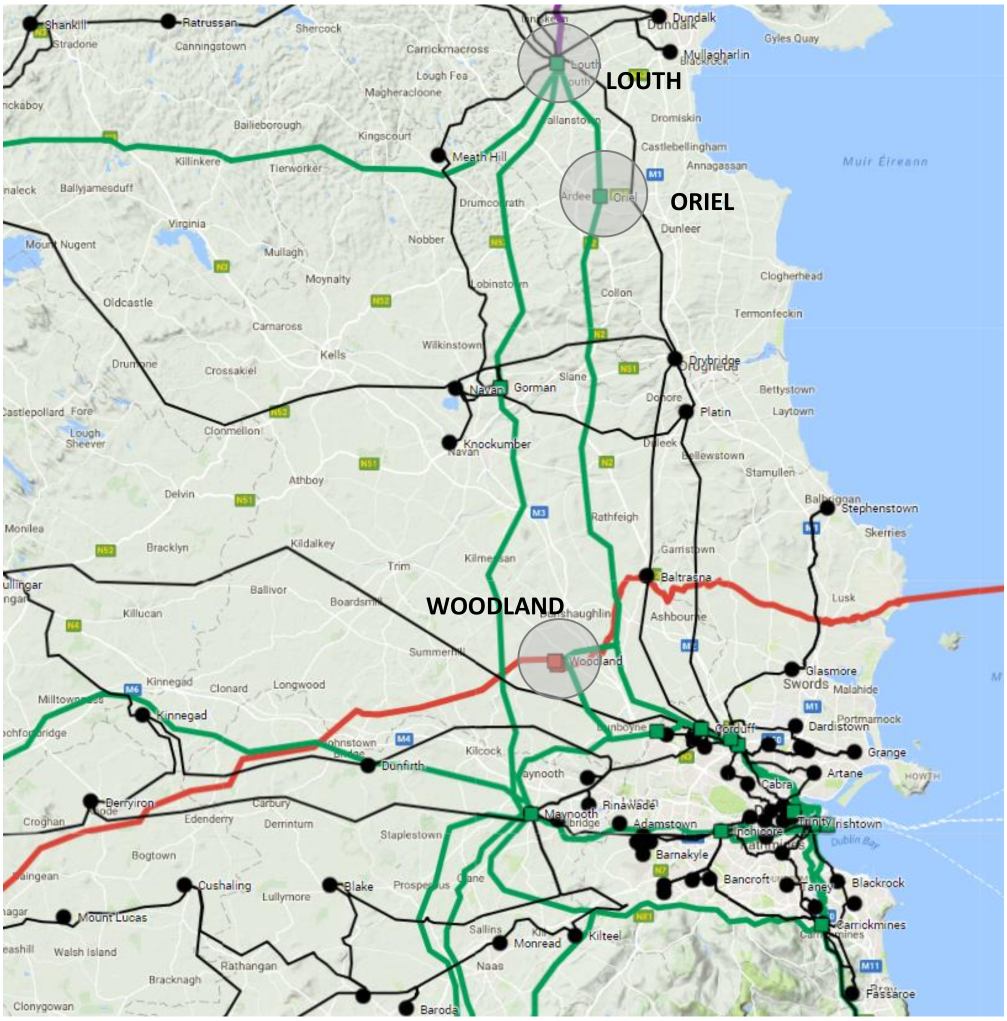

Figure 6-1: Geographical and Electrical Representation of the Meath and Louth Area (exact location of Oriel substation has not been confirmed)

6.2. Louth Opportunities

6.2.1. Existing Network

The analysis indicates that a maximum of 450 MW of offshore wind can be connected at Louth before overloads become a restriction.

With 800 MW of offshore wind at Louth 220 kV busbar, overloads can occur in the intact network on the Louth-Woodland 220 kV circuit under various dispatch conditions and system configurations. Excessive overloads could occur on Gorman-Louth 220 kV circuit for the loss of Louth-Woodland 220 kV circuit and vice-versa.

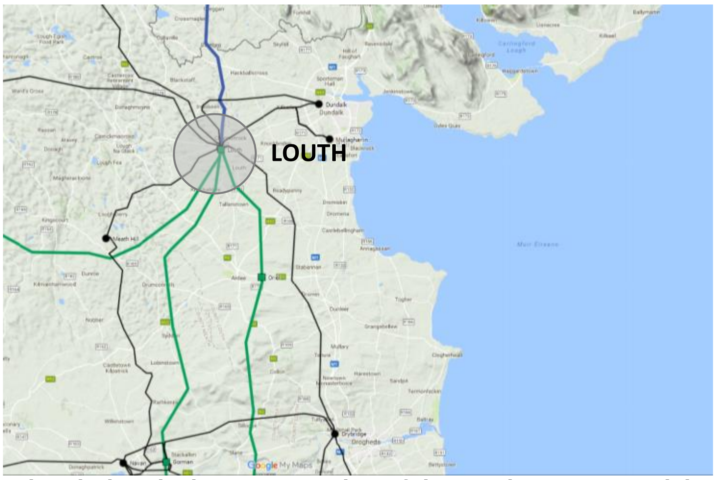

Figure 6-2: Geographical and Electrical Representation of the North East network including Louth 275 /220 /110 kV Substation

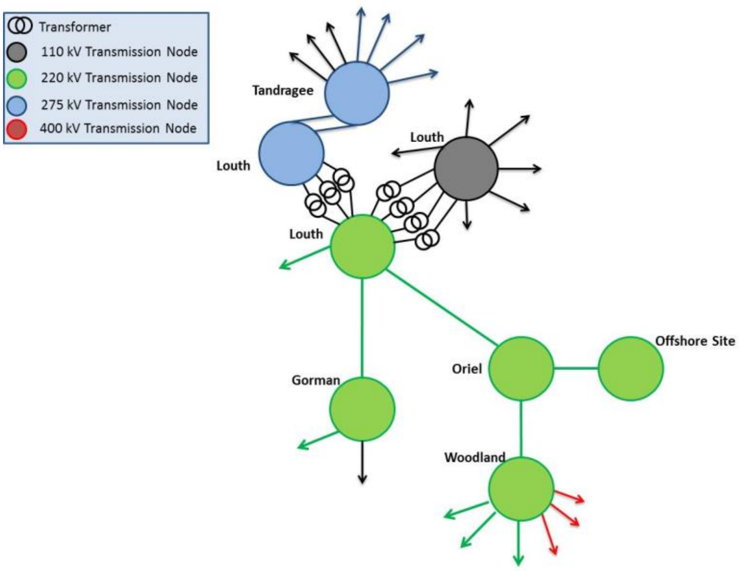

Figure 6-3: Node Diagram of the Louth 275/220/110 kV substation and connections

6.2.2. Network Solutions

The following projects will improve the capability of Louth to accommodate additional offshore wind above 450 MW:

- The completion of the planned North-South 400 kV interconnector will provide an additional path for North-South power flows and thereby reduce the overloads on Gorman-Louth and Louth-Woodland circuits.
- Similarly, the planned project Capital Project 966 will improve connectivity between Dunstown and Woodland and reduces overloads on the Gorman-Louth circuit.
- In addition, to these two projects which are already planned, a further new project would be required to increase the capacity between Louth and Woodland. This could be achieved for example by an uprate of the Louth-Woodland 220 kV circuit to 761/794 MVA.

With the above reinforcements in place, it was found that 650 MW of offshore wind could be accommodated at Louth 220 kV busbar.

Increasing renewable generation at Louth has an impact on the power flows from wind in the North West of the country. In addition to the reinforcement projects described above, in order to facilitate the connection of 800 MW of offshore wind at Louth, the uprate of Lanesboro - Sliabh Bawn 110 kV circuit and the Lanesboro 110 kV busbar will also have to be completed. These planned uprate projects are currently scheduled for completion in 2024.

6.2.3. Connection Options

The Louth 220 kV substation is located approximately 14 km from the coast (see Figure 6-2). There are no spare, equipped 220 kV bays at the substation. However an initial assessment has shown that there is physical space for up to four additional 220 kV bays in the substation. A detailed site investigation would be required to confirm if it is possible to accommodate additional 220 kV bays.

It should be noted that Louth substation is due to undergo major refurbishment work that could have some impact on the options and timing for new connections into the substation. However, it is currently estimated that there will continue to be space available for up to four 220 kV bays.

6.3. Oriel Opportunities

6.3.3. Existing Network

It should be noted that the figures presented in Table 6-1 are the total levels of wind that can be connected at Oriel 220 kV busbar i.e. they are inclusive of the planned 210 MW wind generation already contracted to connect at Oriel. The results for Oriel are quite similar to the result for Louth. However, for existing network conditions, Oriel has slightly less capacity than Louth. This is because there is effectively only two 220 kV circuits out of Oriel. The loss of the Louth-Oriel 220 kV circuit causes an overload on the Oriel-Woodland circuit. This limits the capacity for offshore wind at Oriel to 400 MW.

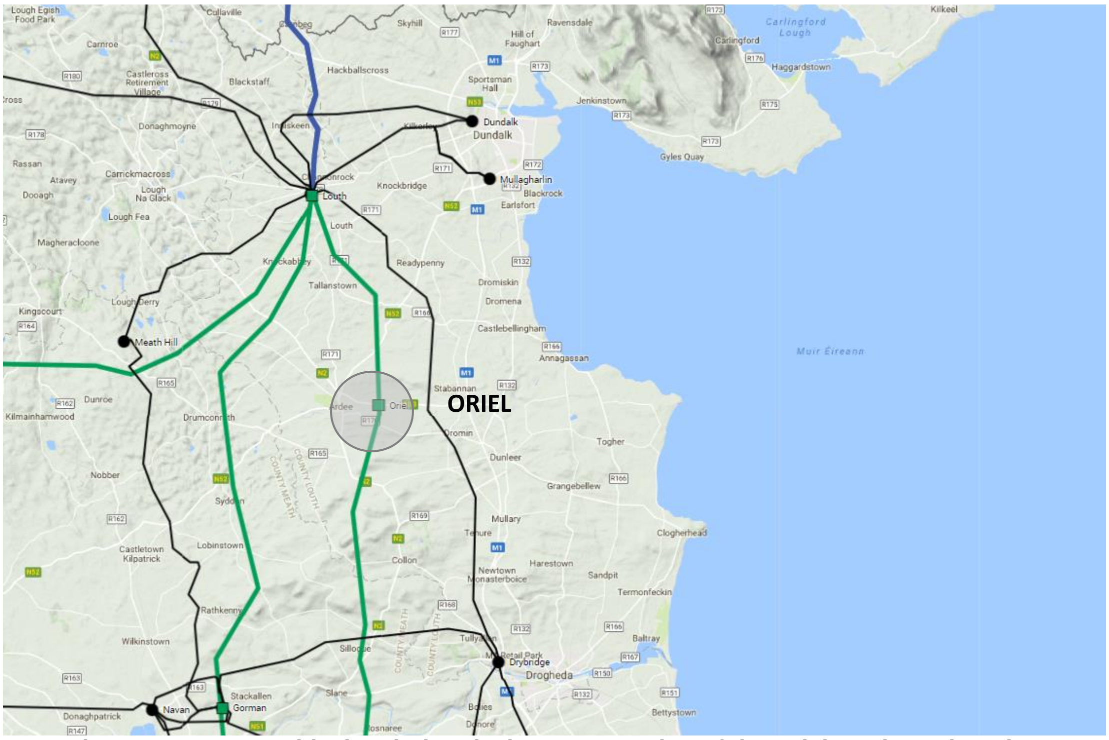

Figure 6-4: Geographical and Electrical Representation of the Oriel 220 kV Substation

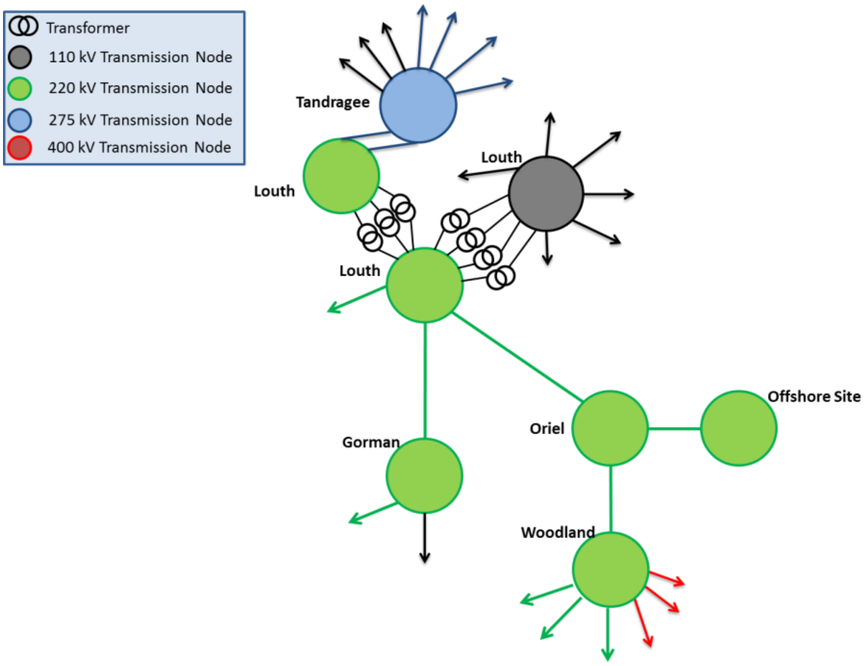

Figure 6-5: Node Diagram of the Oriel 220 kV substation

6.3.4. Network Solutions

The same sequence of works described in Section 6.2.2 would be required in order to connect 650 MW of offshore wind at Oriel. These are:

- The completion of the planned North-South 400 kV interconnector.
- The planned project Capital Project 966.
- A new project to increase the capacity between Louth and Woodland (for example an uprate of the Louth-Woodland 220 kV circuit to 761/794 MVA).

Similarly, the following additional reinforcement would be required in order to connect 800 MW of offshore wind at Oriel:

- Uprate of Lanesboro - Sliabh Bawn 110 kV circuit and the Lanesboro 110 kV busbar

(Note: as stated in Section 3.1, the capacity opportunity information presented in this report is not cumulative; hence these reinforcements will not facilitate 800 MW at Louth and 800 MW at Oriel).

6.3.3. Connection Options

The specific location for the new Oriel substation has not yet been defined. As this will be a new substation it is assumed that it will be possible to provide some synergies for facilitating further connections in this area.

6.4. Woodland Opportunities

6.4.3. Existing Network

Woodland 400/220 kV substation represents an extremely strong part of the network. The analysis has shown that a maximum of 800 MW of offshore wind could be accommodated at Woodland 220 kV busbar.

The initial assessment considered the impact of 800 MW of offshore wind at Woodland 220 kV busbar during standard merit order dispatch of conventional generation. The analysis indicated that 800 MW of offshore wind and imports on the EWIC interconnector could cause overloads on the Corduff-Woodland and Clonee-Woodland 220 kV circuits. Circuit overloads are exacerbated if critical 220 kV circuits in the area are out of service.

The analysis identified that the overloads could be mitigated by reconfiguration of the conventional thermal generation in the Dublin area (see Section 3.3.1). With this mitigation in place the analysis indicated a maximum of 800 MW of offshore wind can be connected at Woodland. It is also recognised that full import on the East West Interonnector interconnector during a high wind period is expected to occur infrequently.

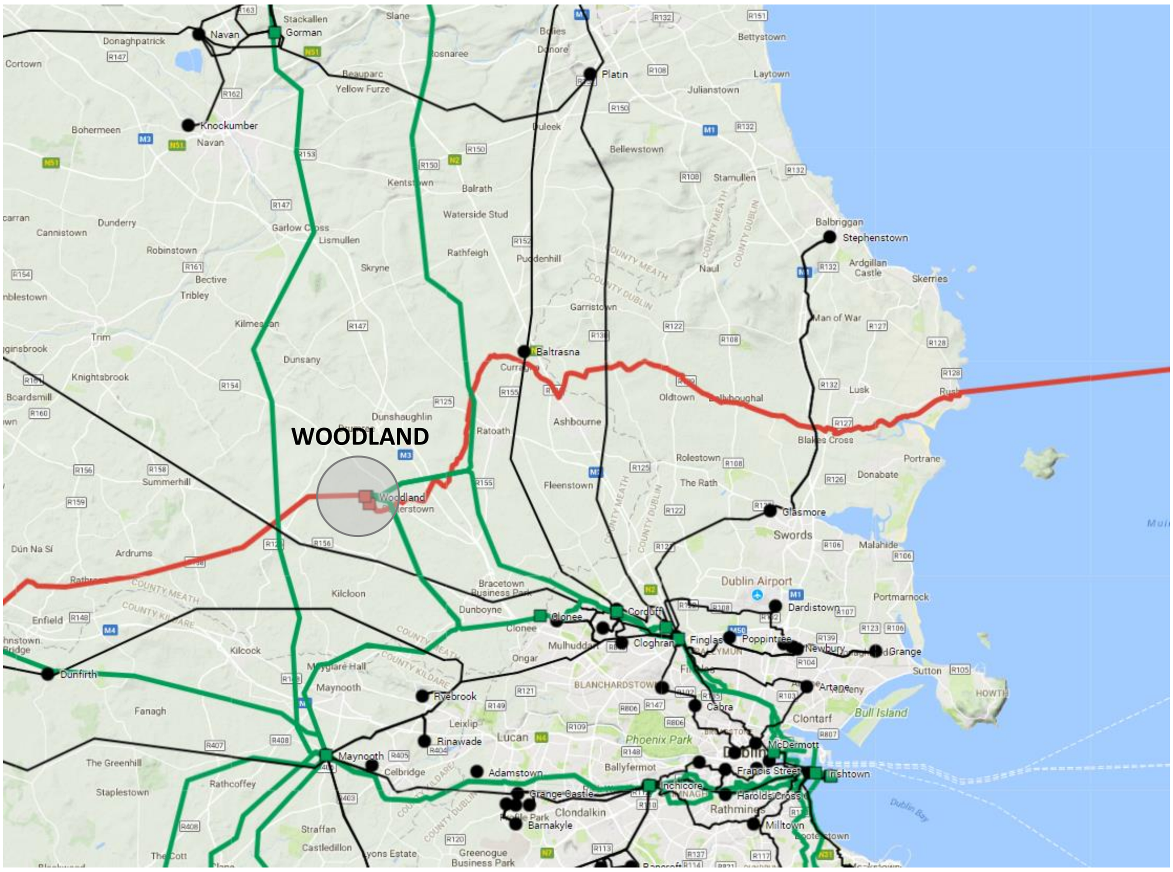

Figure 6-6: Geographical and Electrical Representation of the Woodland 400/ 220 kV Substation

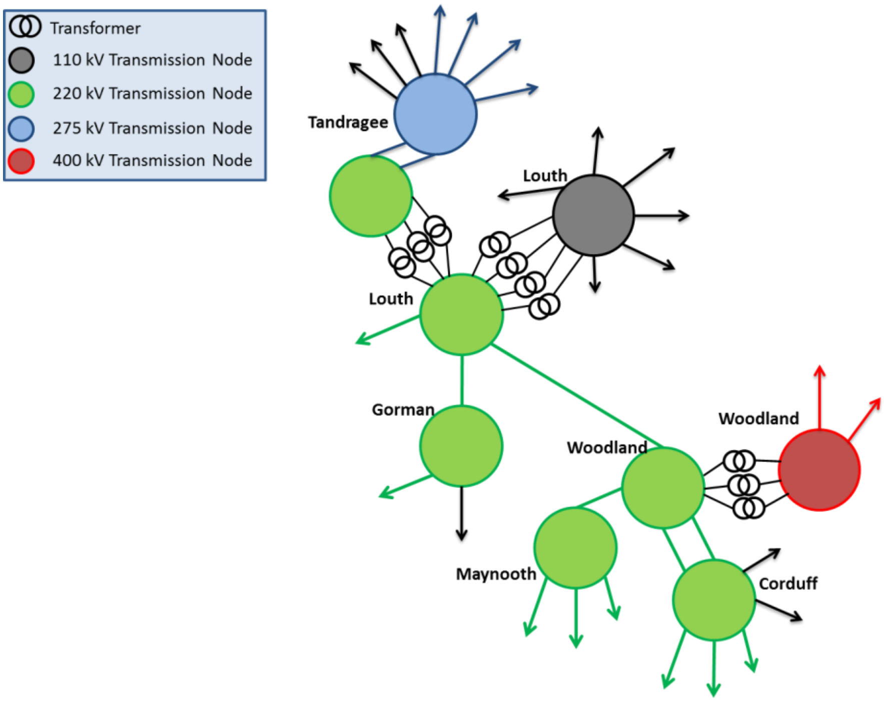

Figure 6-7: Node Diagram of the Woodland 220 kV substation

6.4.4. Connection Options

The Woodland 400/220 kV substation is located approximately 30 km from the coast. There are no spare, equipped 220 kV bays. An initial assessment has shown that there could be physical space for two additional 220 kV bays in the substation. A detailed site investigation would be required to confirm if it is possible to accommodate additional 220 kV bays.

6.5. Opportunities for new Conventional Generation

The assessment considered the impact of 450 MW of high-merit conventional thermal generator at Louth or Woodland during standard merit order dispatch of other conventional generation.

The analysis indicated overloads on the network between Woodland and Corduff. These issues are directly linked to the dispatch assumptions. Unlike for priority dispatch wind, it is assumed that these overloads cannot be mitigated by reconfiguration of the conventional thermal generation in the Dublin area.

A solution would be required to facilitate increased power flows out of Woodland. This could include, for example, a new Woodland to Corduff circuit.

In addition to the Woodland-Corduff issues, it is expected that a 450 MW generator at Oriel would result in a requirement to uprate the Louth-Woodland 220 kV circuit to 761/794 MVA.

7. Dublin City Area Opportunities

This study area can be described as the area between the Poolbeg and Finglas 220 kV substations (see Figure 7-1). Connection could be to a new 220 kV substation; however, given the urban environment of the circuits between Poolbeg and Finglas it is expected that a direct connection into either Poolbeg or Finglas substations is more likely. Connections could also be considered into the new Belcamp 220 kV substation currently under construction. The analysis in this report has focused on opportunities for new generation at Poolbeg and Finglas. This is because these locations are expected to provide the maximum amount of new generation capacity due to the larger number of circuits which connect these substations to the wider Dublin network.

Poolbeg is a 220/110 kV substation in the central part of the city. Poolbeg has five 220 kV circuits and two 220/110 kV transformers. Poolbeg also has an interbus reactor which helps to facilitate the splitting of the Dublin 220 kV network into North and South sections[12]. For this reason, the analysis considered Poolbeg as two locations; Poolbeg North which feeds into the North Dublin transmission network and Poolbeg South feeding the South Dublin transmission network. The power flow on the circuit between Carrickmines and Poolbeg can be controlled by a Phase Shifting Transformer.

Finglas 220/110 kV substation is connected by four 220 kV circuits and has four 220/110 kV transformers. One Huntstown generator (HNC) also connects directly to Finglas at 220 kV. A new Belcamp 220 kV substation will be connected from Finglas in early 2019. The new substation will initially only be supplied from Finglas. Phase 2 of this project will loop Belcamp into the Finglas-Shellybanks circuit and create a Finglas-Belcamp-Shellybanks circuit as shown on the right in Figure 7-5.

7.1. Summary of Opportunities for new Offshore Wind Generation

The results are summarised in the following table. Please see the subsequent sections for specific details of the limitations and potential mitigations.

Table 7-1: Summary of Dublin City Area Offshore Opportunities

Location	Offshore Capacity (MW)	Network Conditions or Assumed Reinforcement	Substation Space
Poolbeg North	600	Base Case	2x bays
	800	Finglas-North Wall-Poolbeg 220 kV new cable	
Poolbeg South	800	Base Case	2x bays
Finglas	800	Base Case	1x bay

12 Sectionalising is also applied at Shellybanks 220 kV substation

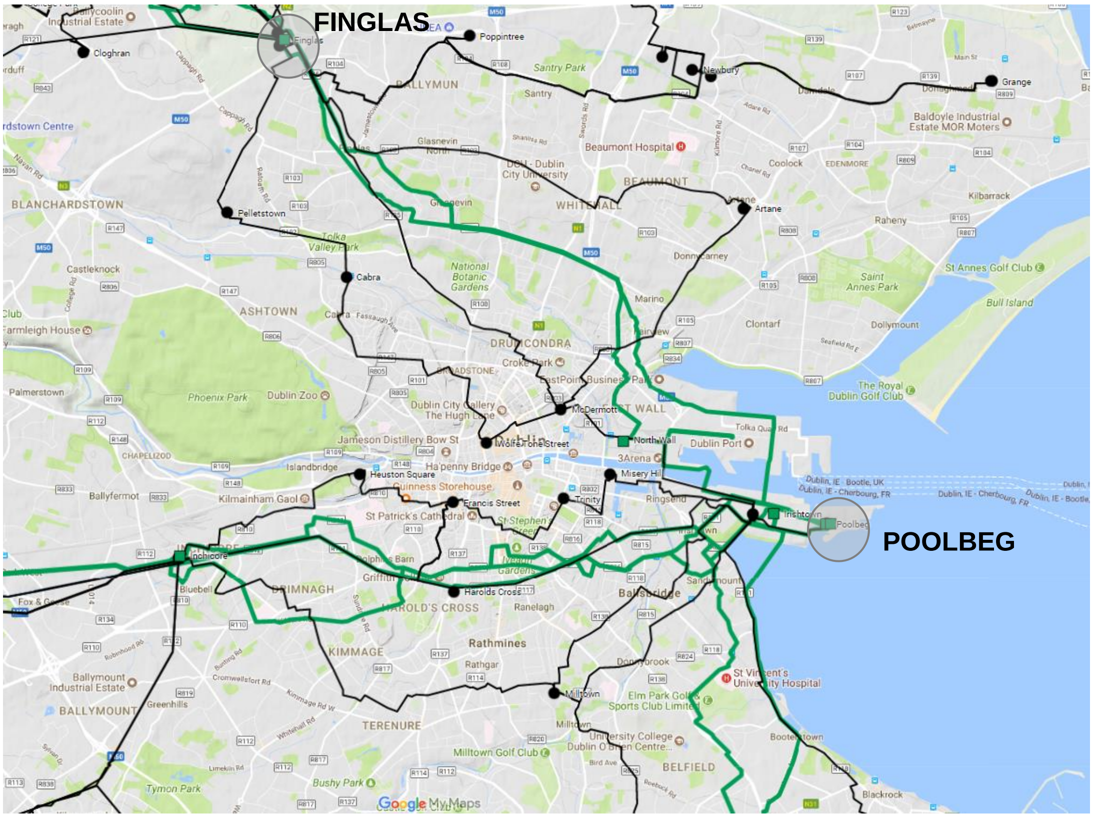

Figure 7-1: Geographical and Electrical Representation of the Dublin City Area

7.2. Poolbeg (North) Opportunities

7.2.1. Existing Network

The analysis identified that there are opportunities for a maximum of 600 MW of offshore wind to connect at Poolbeg (North).

The initial assessment considered the impact of 800 MW of offshore wind at Poolbeg (North) during standard merit order dispatch of conventional generation. The analysis indicated that 800 MW caused overloads in the intact network (where all transmission circuits are available) on North Wall-Poolbeg and the Finglas-North Wall 220 kV circuits. Circuit overloads are exacerbated if critical 220 kV circuits in the area are out of service (particularly Poolbeg-Shellybanks or Belcamp-Shellybanks).

The analysis identified that the overloads could be partially mitigated by reconfiguration of the conventional thermal generation in the Dublin area (see Section 3.3.1). With this mitigation in place the analysis indicated a maximum of 600 MW of offshore wind can be connected at Poolbeg (North).

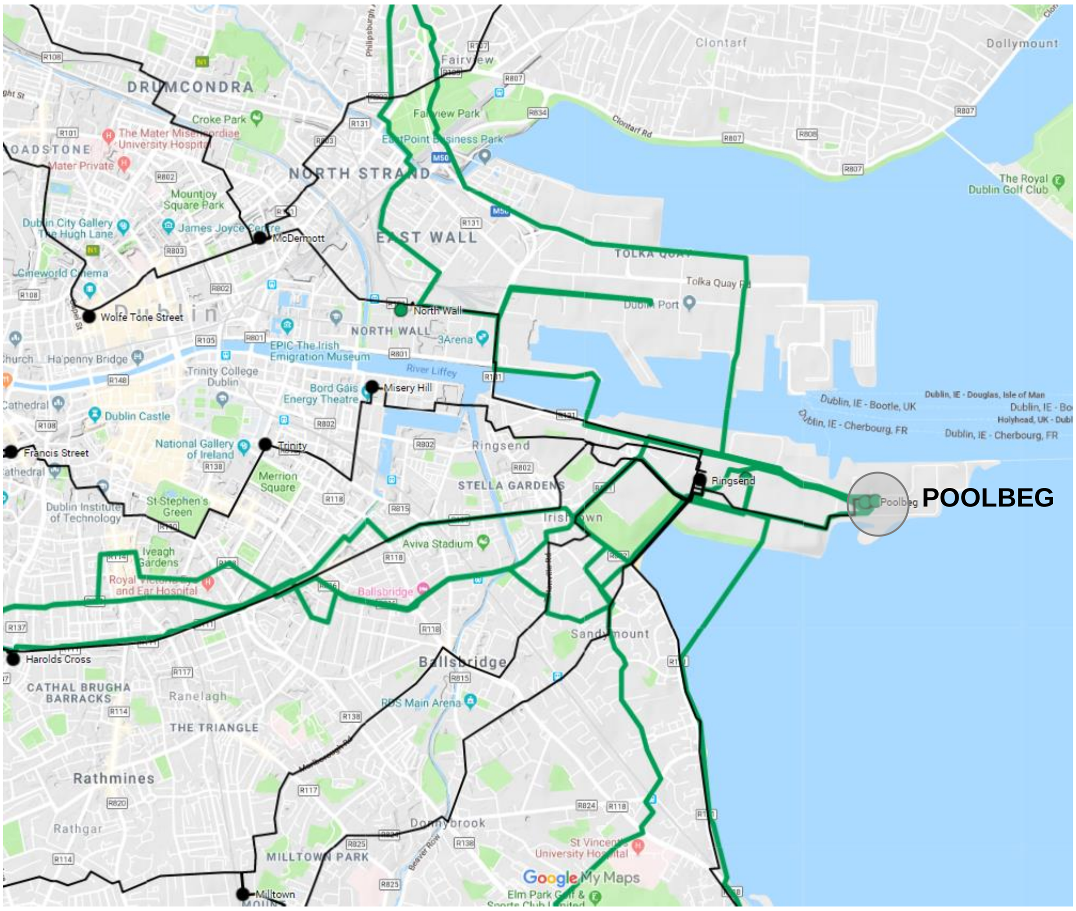

Figure 7-2: Geographical and Electrical Representation of the Dublin City Area

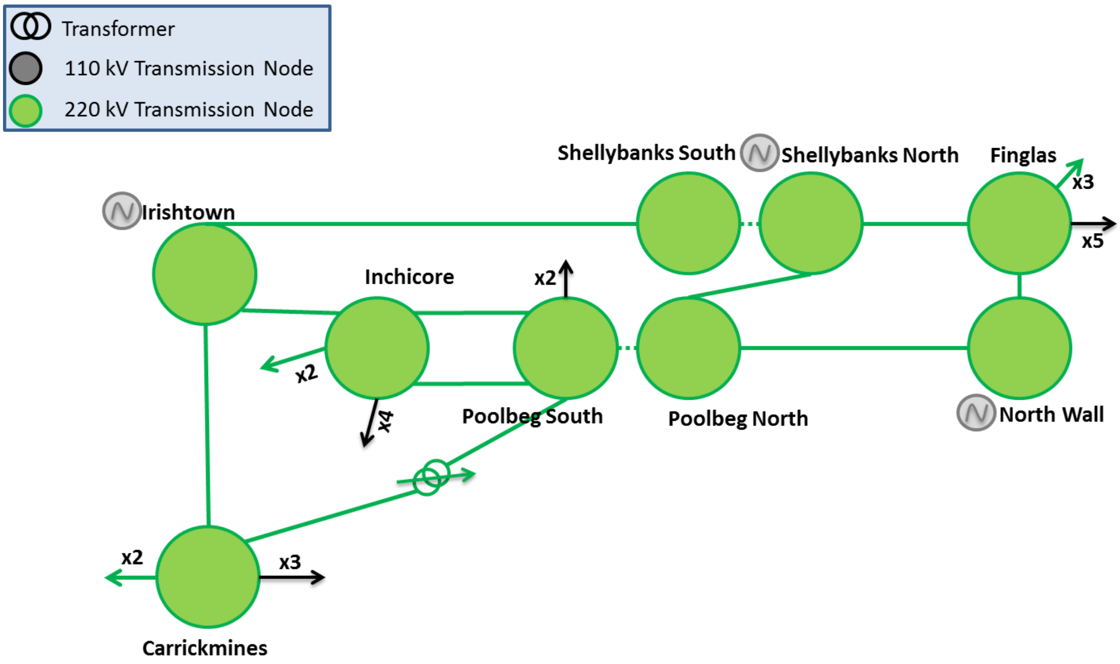

Figure 7-3: Simplified illustration of the 220 kV network at Poolbeg

7.2.2. Network Solutions

In order to connect 800 MW of offshore wind at Poolbeg (North), a solution would be required to facilitate increased power flows from Poolbeg to Finglas. This could include, for example, increasing the capacity of the Finglas-North Wall and North Wall-Poolbeg 220 kV circuits to a minimum rating of 570 MVA. As these circuits are composed entirely of underground cables (as opposed to overhead line) a new 220 kV cable would be required between Finglas, North Wall and Poolbeg.

7.2.3. Connection Options

The Poolbeg 220 kV substation is located in the Dublin Port area and is less than 0.5 km from the coast (see Figure 7-2). The 220 kV busbar is a mix of AIS and GIS technologies. An initial assessment has indicated that the substation space could be quite constrained. Two bays have recently been allocated for new reactors to help control voltages during low-demand periods. A number of bays were allocated to generation that has now closed; it is expected that these bays would be available for new connections. Detailed site investigation would be required to confirm the final amount of available bays and the status of the equipment in these bays. It is expected that the busbar will have a sufficient level of operational flexibility to configure the feeding arrangements of the off-shore wind to feed either into North or South Dublin regardless of the busbar connection point.

7.3. Poolbeg (South) Opportunities

7.3.1. Existing Network

The analysis shows that 800 MW of offshore wind could be accommodated at Poolbeg (South).

The initial assessment considered the impact of 800 MW of offshore wind at Poolbeg (South) during standard merit order dispatch of conventional generation. The analysis indicated that 800 MW caused overloads in the intact network (where all transmission circuits are available) on the Inchicore-Poolbeg no. 1 and the Inchicore-Poolbeg no. 2 220 kV circuits. Circuit overloads are exacerbated if critical 220 kV circuits in the area are out of service (particularly either of the Inchicore-Poolbeg circuits).

The analysis identified that the overloads could be mitigated by reconfiguration of the conventional thermal generation in the Dublin area (see Section 3.3.1). With this mitigation in place the analysis indicated a maximum of 800 MW of offshore wind can be connected at Poolbeg (South).

7.3.2. Connection Options

As defined in Section 7.2.3 it is expected that there may be spare bays available at Poolbeg and that the busbar will have a sufficient level of operational flexibility to configure the feeding arrangements of the off-shore wind to feed either into North or South Dublin regardless of the busbar connection point.

7.4. Finglas Opportunities

7.4.1. Existing Network

The initial assessment considered the impact of 800 MW of offshore wind at Finglas 220 kV busbar during standard merit order dispatch of conventional generation. The analysis indicated that 800 MW of offshore wind could cause overloads on the Corduff-Finglas no.1 and Corduff-Finglas no.2 220 kV circuits. Circuit overloads are exacerbated if critical 220 kV circuits in the area are out of service (particularly either of the Corduff-Finglas circuits).

The analysis identified that the overloads could be mitigated by reconfiguration of the conventional thermal generation in the Dublin area (see Section 3.3.1). With this mitigation in place the analysis indicated a maximum of 800 MW of offshore wind can be connected at Finglas.

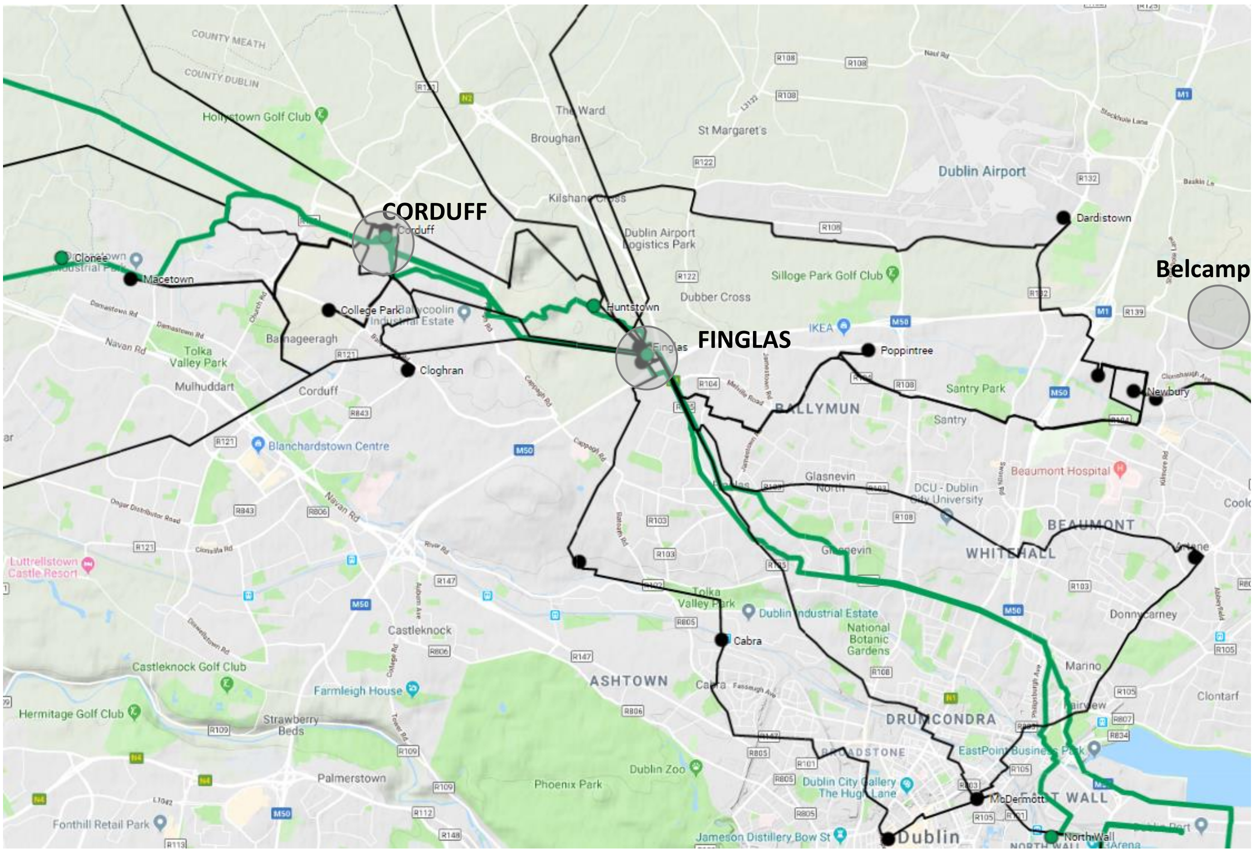

Figure 7-4: Geographical and Electrical representation of the Corduff, Finglas and Belcamp 220 kV substations

7.4.2. Connection Options

The Finglas 220 kV substation is approximately 13.5 km from the coast (see Figure 7-4). An initial assessment has indicated that the substation space is very constrained. It is anticipated that expansion of the 220 kV busbar would be extremely difficult. There may be a spare bay created in the future following the diversion of the Shellybanks circuit to form the Belcamp-Shellybanks circuit. This should make the existing Shellybanks bay available for other uses.

Connections could also be considered into other nearby substations such as Corduff and Belcamp 220/110 kV substations. Further analysis would be required to confirm the specific capacity available at these locations.

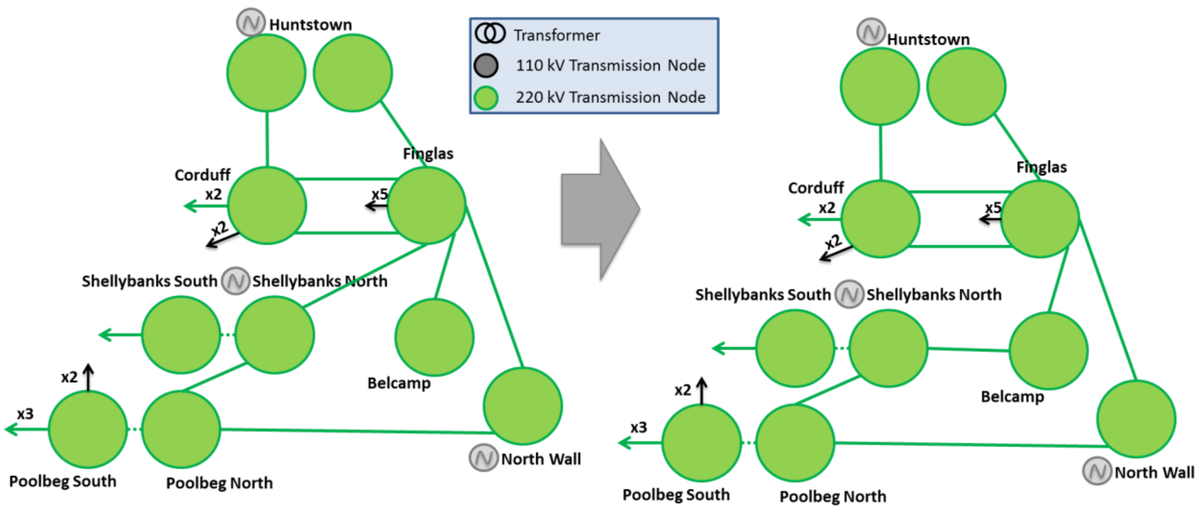

Figure 7-5: Simplified illustration of the 220 kV connections to Finglas following the completion of Belcamp Phase 1 (left) and Belcamp Phase 2 (right)

7.5. Opportunities for new Conventional Generation

The analysis shows that a 450 MW high-merit conventional thermal generator could be accommodated at Poolbeg (North and South) and Finglas.

This result is specifically related to the assumption that the new generator would be very high in the merit order and therefore likely displace some existing conventional generation in these areas. This ensures that excessive power flows do not occur on certain critical circuits such as between Inchicore and Poolbeg and between Finglas and Corduff.

8. Summary

A summary of the generation opportunities for offshore wind connections is shown in Table 8-1. The available space at each substation is also given in Table 8-1.

Table 8-1: Summary of Offshore Opportunities

Location	Offshore Capacity (MW)	Network Conditions or Assumed Reinforcement	Substation Space
Carrickmines	650	Base Case	3 x bays
	350	If 350 MW assumed connected at Arklow	
	800	New Carrickmines-Poolbeg circuit	
Ballybeg	500	Upvoltage Ballybeg-Carrickmines	New Substation
	700	Upvoltage and uprate circuits to Carrickmines	
Arklow	350	Base Case (Ballybeg bay conductors uprated)	2x bay Space
	500	Upvoltage Arklow-Ballybeg-Carrickmines	
	800	Upvoltage and uprate Arklow-Ballybeg-Carrickmines	
Louth	450	Base Case	4 x bay space
	650	North South, CP966, uprate Louth-Woodland	
	800	As above and Sliabh Bawn-Lanesboro and Lanesboro busbar uprate	
Oriel	400	Base Case	New Substation
	650	North South, CP966, uprate Louth-Woodland	
	800	As above and Sliabh Bawn-Lanesboro & Lanesboro busbar uprate	
Woodland	800	Base Case	2 x bay space
Poolbeg	600	Base Case	2 x bays

North	800	Finglas-North Wall-Poolbeg 220 kV circuit	
Poolbeg South	800	Base Case	2 x bays
Finglas	800	Base Case	1 x bay

9. Conclusion

All areas were shown to have considerable capacity available for new generation. The results indicate that locations close to the Dublin load centre and/or with multiple 220 kV connections into the Dublin area have the best opportunities for new generation capacity. Arklow and Louth locations have less opportunities available because these locations have less (typically only one) 220 kV transmission connections to Dublin.

Potential developers who are considering new generator connections and wish to discuss the content of this document are encouraged to contact us[13]. This report is intended to provide indicative opportunity information to potential new developers of power sources on the East Coast and should be considered in parallel with the EirGrid Tomorrow's Energy Scenarios documentation, and the generation opportunity section in the All Island Ten Year Transmission Forecast Statement.

Any developer looking to progress a project will have to apply through the appropriate channels and would be processed through the Connection Offer Process[14]. The content of this report should not be taken to prejudge the outcome of the official Offer Process.

In addition to power flow studies, a new connection may also require additional detailed studies such as; short circuit analysis, stability studies and power quality studies.

[13] http://www.eirgridgroup.com/contact/
[14] Applications for generation are currently being processed per Enduring Connection Policy (ECP-1)