I-SEM
Capacity Market:
Locational Capacity Constraints Methodology

03 July 2017

Disclaimer

EirGrid and SONI have followed accepted industry practice in the collection and analysis of data available. While all reasonable care has been taken in the preparation of this data, EirGrid and SONI are not responsible for any loss that may be attributed to the use of this information. Prior to taking business decisions, interested parties are advised to seek separate and independent opinion in relation to the matters covered by this report and should not rely solely upon data and information contained herein. Information in this document does not amount to a recommendation in respect of any possible investment. The use of information contained within this consultation paper for any form of decision making is done so at the user's sole risk.

Table of Contents

Definitions and Terms

Terminology	Meaning
AC Load flow	A numerical analysis of the flow of electric power in an interconnected alternating current power system
Capacity Auction	Annual capacity market auction where Generator Units, Demand Side Units, Interconnectors and Autoproducer sites compete to meet a capacity requirement (adjusted accordingly by the Regulatory Authorities).
Capacity Market	The new I-SEM capacity arrangements including qualification, Capacity Auctions, secondary trading and settlement.
Capacity Requirement	The quantity of de-rated capacity (MW) that is required to satisfy the SEM adequacy standard for the demand scenario chosen by the least-worst regrets analysis.
Transmission Constraint	A limitation on the transmission network for which the requirements of the TSSPS is not satisfied.
Contingency	The unexpected failure or outage of a system component, such as a generation unit, transmission line, circuit breaker, switch, or other electrical element.
De-rating Factor	The proportion of a unit's capacity that it can offer in the auction. The De-rating Factor accounts for the units' reliability and its contribution to generation adequacy. As the auction is based on a de rated requirement, using De rating Factors helps to ensure that the adequacy standard is satisfied for any given combination of auction outcomes.
Fault Levels	The maximum or minimum current (depending on the application) at any given point on an electricity transmission network that would flow in case of a short circuit fault at that point.
Generation Capacity Statement or GCS	An annual report produced by the TSOs that forecasts the future demand for electricity and the generation capacity that would be required to meet this demand in accordance with the generation adequacy standards for Ireland, Northern Ireland and on an all-island basis.
Least-Worst Regrets	A method of identifying the option/decision capable of producing an outcome that has the least negative result over a range of plausible scenarios.
Loss of Load Expectation or LOLE	A probabilistic assessment of the number of hours in the year where the demand is expected to exceed available capacity.
Locational Capacity Constraint	A constraint that applies in a Capacity Auction to ensure that the Locational Capacity Constraint Minimum Requirement clears from Capacity Market Units located in the Locational Capacity Constraint Area.

Terminology	Meaning
Locational Capacity Constraint Area	The area to which the Locational Capacity Constraint applies, defined by reference to the relevant Transmission System and Distribution System (and nodes on the Transmission System and Distribution System, as applicable).
Locational Capacity Constraint Level	The nesting level of a Locational Capacity Constraint (which shall be either Level 1 or Level 2) where: • a Level 2 Locational Capacity Constraint Area is entirely contained in a Level 1 Locational Capacity Constraint Area, and • Locational Capacity Constraint Areas of the same level do not overlap.
Locational Capacity Constraint Minimum Requirement	The minimum quantity of de-rated capacity that is to be cleared in a Capacity Auction in respect of a Locational Capacity Constraint.
Meshed Transmission System / Meshed System	A transmission network topology characterised by multiple circuits connecting to each node or station so that the loss of a single line does not disrupt the flow of power to consumers.
Peak Demand	The peak demand that is transported on the network. The peak demand includes network losses.
Power Transfer	The transfer of electrical power between circuits, devices, equipment, or systems. For example, the transfer of electrical power from a generator to an electrical load or from one group of transmission lines to another.
Power transmission system planning software or PSS®E	A software package developed and maintained by Siemens PTI for the analysis and planning of the transmission system.
Transmission System Security and Planning Standards or TSSPS	The standards that are applied in transmission planning and operation.
All-Island Ten Year Transmission Forecast Statement or TYTFS	An annual report produced by the TSOs that provides information regarding the contracted generation capacity and network demand for the all-island transmission system (with associated network models and data).

Executive Summary

In the context of the new Capacity Market, which is based on a set of annual Capacity Auctions, it is likely that the total existing de-rated capacity on the system will exceed the capacity requirement for the Capacity Auction. There are also likely to be, at least initially, constraints on the transmission network, which place limits on how much power can be transmitted from one point the system to another. The transmission system is therefore not indifferent to the location of capacity required to meet security of supply requirements.

As a result the Regulatory Authorities published the Locational Issues decision paper (SEM-16-081) which tasked the Transmission System Operators with developing a methodology for the determination of Locational Capacity Constraints that will be used as inputs into future Capacity Auctions. This document details the methodology for defining constraint areas and their associated minimum requirements in order to satisfy the SEM Committee decision.

The approach builds on existing tools and standards and makes use of prevailing and approved data sources. Where appropriate, the methodology uses the same approach and assumptions used to calculate the All-Island Capacity Requirement. The approach is consistent with that used to identify transmission network constraints and their corresponding reinforcements as detailed in the All-Island Ten Year Transmission Forecast Statement.

The methodology focuses on power transfer constraints only. Safe and secure operation of the power system will continue to require investment in ancillary services which is not addressed as part of this scope of work.

The methodology set out in this document combines existing network planning and generation adequacy tools and standards into a framework that can fulfill the requirements set out in SEM-16-081. These tools and standards are already used by the Transmission System Operators. In this consultation feedback is sought on the proposed framework for combining them to deliver on the requirements set out in SEM-16-081.

1 Introduction

1.1 Background

As part of the I-SEM high level design process the SEM Committee decided that there would be *"an explicit capacity remuneration mechanism to help deliver secure supplies for consumers in the all-island market, particularly with increasing variable generation".*

In the near term, there will likely be more existing capacity on the system than will be procured through the initial Capacity Market auctions. There is also likely to be, at least initially, constraints on the transmission network. In this context, the transmission system is not indifferent to the location of capacity required to meet security of supply requirements.

As a result the Regulatory Authorities published a Locational Issues Decision paper (SEM-16-081[1]) in December 2016 which set out key decisions and principles. Following this paper, the SEM Committee tasked the Transmission System Operators with developing a methodology for the determination of Locational Capacity Constraints that will be used as inputs into future Capacity Auctions. This document details the methodology for defining constraint areas and their associated minimum requirements in order to satisfy the SEM Committee decision.

The Capacity Requirement and De-rating Factors for the Capacity Market auction are calculated according to the methodology set out in SEM Committee Decision SEM-16-082[2]. The de-rating factors are the proportion of the unit's capacity that it can offer in the auction and accounts for outages and variable generation etc. The de-rated Capacity Requirement for the auction is the total de-rated capacity that is required to satisfy the all-island unconstrained adequacy standard. The all-island adequacy standard will continue to be eight hours loss of load expectation (LOLE).

It is expected that the methodology will identify a limited number of Locational Capacity Constraint Areas where power transfer constraints limits bind. A minimum MW requirement will be calculated for each of the locational constraint areas identified (see Figure 1 for an illustration). The auction is then designed to ensure (where possible) that a minimum amount of capacity clears in the areas that those constraints apply to.

---

1 https://www.semcommittee.com/publication/sem-16-081-crm-locational-issues-decision-paper
2 https://www.semcommittee.com/publication/sem-16-082-crm-capacity-requirement-and-de-rating-methodology-decision-paper

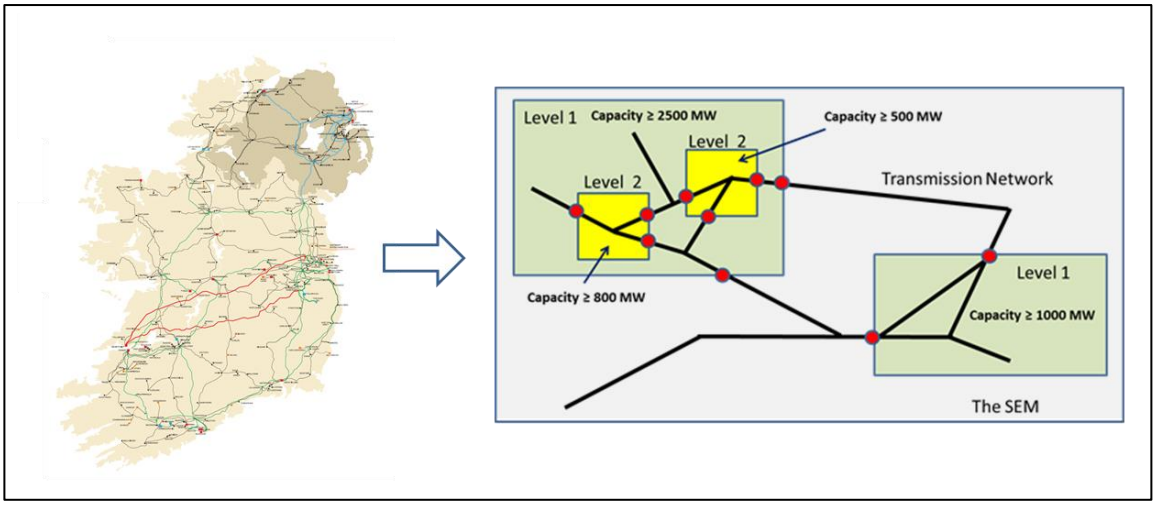


Figure 1: The aim of the methodology is to make an assessment of the transmission system to identify locational capacity constraints. Based on the identified constraints, Locational Capacity Constraint Areas are defined and a minimum MW requirement calculated for each area.

The constraints are to be set "for the purpose of system security" and are required to address only capacity related constraints.

1.2 Relevant SEM Committee Decisions

The methodology described in this document is in compliance with the following SEM Committee Decisions:

- SEM-16-081: Capacity Remuneration Mechanism Locational Issues Decision Paper, 8 December 2016; and
- SEM-16-082: Capacity Requirement and De-Rating Factor Methodology, Detailed Design, Decision Paper, 8 December 2016.

1.3 Document Scope

The Transmission System Operators (TSOs) have been tasked by the SEM Committee to develop a methodology for the determination of Locational Capacity Constraints that will be used to set inputs into future Capacity Market Auctions. This document sets out the approach that the TSOs adopt to determine these inputs.

The methodology set out in this document combines existing network planning and generation adequacy tools and standards into a framework that can fulfill the requirements set out in SEM-16-081.

1.4 Document Outline

This document is structured as follows:

- Overview of the methodology in which the overall scope of the method is discussed;
- The methodology overview is then explained in detail, adhering to the structure presented in the overview, namely:
    - The sources of input data are listed and discussed;
    - Using the data sources, the assumptions that are made in order to perform the necessary analysis are presented;
    - The approach taken to identify Locational Capacity Constraint Areas and the transmission nodes associated with them; and
    - The calculation methodology for determining the de-rated capacity required to located in the Locational Capacity Constraint Area which will be used to set the inputs for the Capacity Market Auction

2 Technical References

There are a number of reference documents used by the methodology. For the purpose of this methodology, the latest published version at the time of the calculation will be used.

An overview of each of the references is provided below:

All-Island Generation Capacity Statement [3]

The Generation Capacity Statement forecasts the future demand for electricity and the generation capacity that would be required to meet this demand in accordance with the generation adequacy standards for Ireland, Northern Ireland and on an all-island basis.

All-Island Ten Year Transmission Forecast Statement [3]

The All-Island Ten Year Transmission Forecast Statement (TYTFS) is prepared each year in accordance with the statutory and licence obligations of the Transmission System Operators in both Ireland and Northern Ireland.

The Forecast Statement provides information regarding the contracted generation capacity and network demand; and network models and data for the all-island transmission system. It also provides a range of other technical performance information, such as predicted transmission system power flows at different points in time and fault levels at transmission stations.

Transmission System Security and Planning Standards [3,4]

The Transmission System Security Planning Standards (TSSPS) set out the standards that are applied in transmission planning and operation. The specific function of transmission planning is to ensure the co-ordinated development of a reliable, efficient, and economical system for the transmission of electricity for the long-term benefit of transmission users.

Planning standards are in place in both Ireland and Northern Ireland and these are aligned and consistent for the majority of the performance criteria. Where there are differences, they typically relate to the different network topologies (e.g. different voltage levels; and the use of double circuit configurations).

[3] http://www.eirgridgroup.com/library
[4] http://www.soni.ltd.uk/

Capacity Requirement and De-rating Factor Methodology

The Capacity Requirement and De-rating Factors Methodology decision paper and associated appendices set out the methodology used by the TSOs to calculate the All-island Capacity Requirement for the Capacity Market auction.

The Capacity Requirement is the quantity of de-rated capacity that is required to satisfy the SEM adequacy standard for the demand scenario selected by the Least-Worst Regrets analysis. It also sets out the methodology to be used to calculate the De-rating Factors for each technology and size class. The De-rating Factor is the proportion of a unit's Initial Capacity (in most cases this is their Maximum Export Capacity) that it can offer in the auction. The De-rating Factor accounts for the unit's reliability and its contribution to generation adequacy.

As the Capacity Auction is based on a de-rated requirement, using De-rating Factors helps to ensure that the adequacy standard is satisfied for any given combination of auction outcomes.

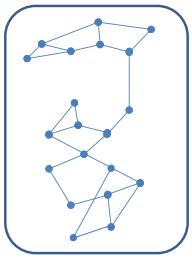
3 Conceptual Overview

This section is intended to provide some context and a conceptual overview of the methodology.

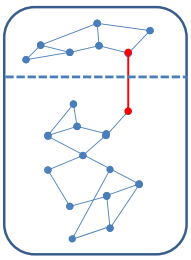
The All-Island Capacity Requirement calculates the quantity of de-rated capacity that is required to satisfy the SEM Loss of Load Expectation (LOLE) adequacy standard and is used to set the Capacity Auction demand curve. That analysis assumes an unconstrained all-island transmission system. In practice, the transmission system does have constraints, which limit the ability to transfer power from one part of the island to another. The purpose of the methodology is to identify significant capacity constraints and to calculate the levels of generation required in constrained areas to ensure security of supply.

The methodology uses the following steps (the diagrams are for illustrative purposes only):

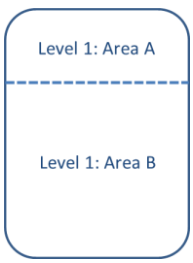
Network Topology Assessment



The first stage of the analysis is a high-level assessment of the transmission network. This assesses if the all-island network complies with some basic network planning standards and will identify if the full all-island network can be treated as one meshed system.



For example, in the absence of the second north-south tie-line, this assessment will indicate that Ireland (IE) and Northern Ireland (NI) should be treated as two non-meshed systems (i.e. connected by a single transmission feeder). This approach does not preclude the identification of further non-meshed areas, but as both the NI and IE systems have been designed as meshed systems, the identification of further non-meshed areas is unlikely.



The dashed line in the diagram on the left illustrates the boundary between the non-meshed areas.

For the purpose of this Locational Capacity Constraint methodology each of the non-meshed areas identified will be defined as a Level 1 Locational Capacity Constraint Area.

The minimum MW requirement in each of the non-meshed Level 1 Locational Capacity Constraint Areas will be calculated by assessing the quantity of de-rated capacity required in each area to satisfy the LOLE adequacy standard.

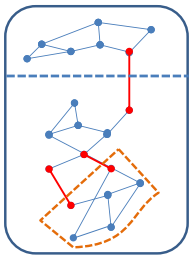
If no non-meshed areas exist, then no constraint areas will be identified by the high level network topology assessment and the analysis moves to the detailed network assessment stage.

Area LOLE Adequacy Assessments

The LOLE adequacy assessments will use a similar approach and assumptions as used in the All-Island Capacity Requirement calculation. However, it will use the portfolio and demand applicable to that area.

This approach will identify the lower bound of the minimum MW requirement in each of the non-meshed Level 1 Locational Capacity Constraint Areas.

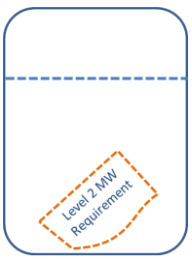
Detailed Network Assessments



The purpose of the detailed network assessments is to identify network capacity constraints within the meshed network which limit power transfer and for which generation in an area would be required to mitigate those constraints. It uses detailed AC Load Flow simulations of a large range of demand-generation combinations.

It tests the ability of the network and only considers constraints that are capacity related. Using the results of the detailed network assessments it is possible to identify constraint areas.

The detailed network assessments can identify a number of Level 1 (for the case where no non-meshed areas exist) and Level 2 capacity constraint areas. While there can be a number of Level 1 and 2 areas, each Level 2 constraint area must reside fully within a Level 1 area.



The detailed network analysis is also used to calculate the minimum MW requirement in the Locational Capacity Constraints Areas identified by the network analysis. This is achieved by iteratively increasing capacity in the Locational Capacity Constraint Area until the constraints are resolved.

Methodology Outputs

The outputs of this methodology will be used to construct a set of inputs for the Capacity Market Auction. The TSOs apply the methodology to identify any Locational Capacity Constraint Areas and their associated minimum MW requirements. The set of transmission or distribution nodes that are within each of the Locational Capacity Constraint Areas are defined. The minimum MW capacity required in each area will be given in de-rated MW.

The Locational Capacity Constraint Areas identified by this methodology will be listed in the Initial Auction Information Pack that will be published prior to qualification. During qualification, units will be required to identify if their network connection is within any of the Locational Capacity Constraint Areas listed in the Initial Auction Information Pack. A Capacity Market Unit must be wholly within an area to be included in the Locational Capacity Constraint Area for the auction.

4 Methodology Framework

This section presents an overview of the methodology framework to be used to determine the Locational Capacity Constraints. The methodology is designed to identify capacity constraints on the all-island transmission system by testing its ability to comply with the security and performance standards.

This methodology is illustrated in the process flow diagram shown in Figure 2 below.

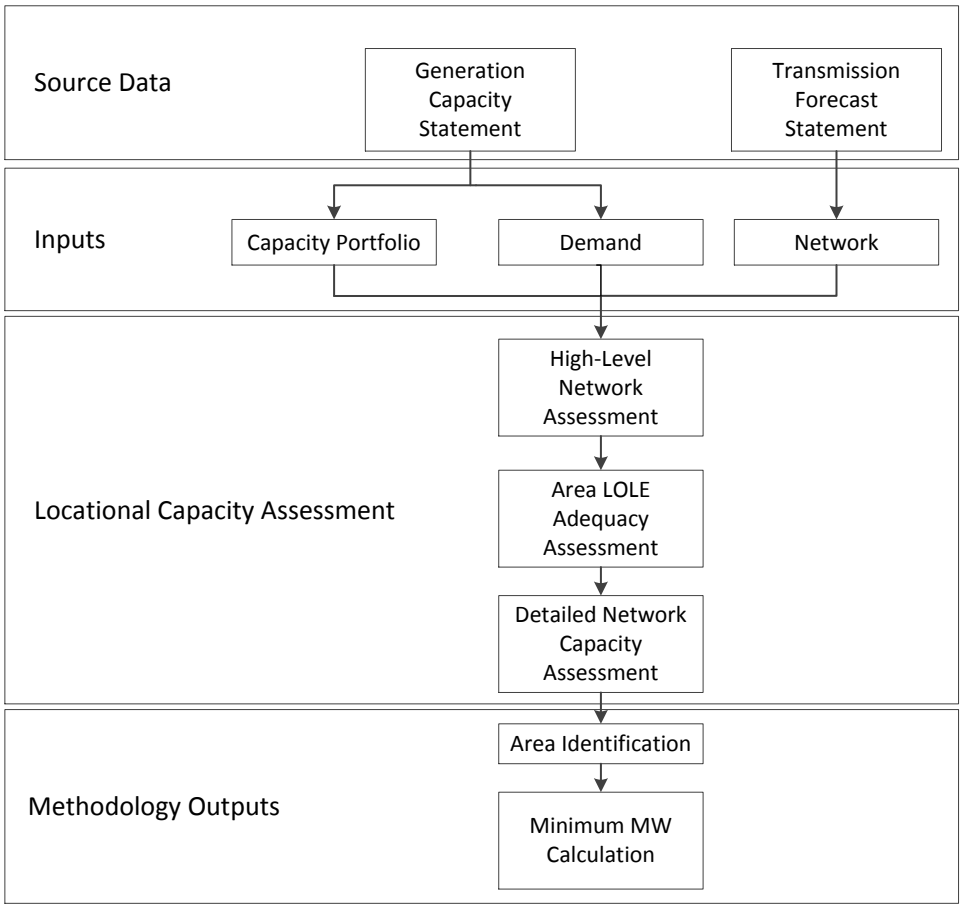


Figure 2: Illustration of Methodology for Determining Locational Capacity Constraints

As shown in Figure 2, the assessment makes use of public documents (i.e. Generation Capacity Statement and the All-Island Ten Year Transmission Forecast Statement) as sources of input data. Furthermore, the approaches and methodologies used in their compilation to assess generation and transmission network adequacy are also made use of in the locational capacity constraints methodology.

The locational capacity assessment involves a number of steps that may be described as follows:

- A high level assessment of transmission system topology. The purpose is to assess if the all-island transmission system can be treated as a meshed system. This is done by testing the all-island network to determine if it complies with some basic network planning standards. This is consistent with the unconstrained market simulation that assumes that the network does not impose a constraint.

- Where the all-island transmission system does not meet the primary measure of network security of supply (i.e. is demonstrated not to be meshed and therefore not capable of providing single contingency capability) it is possible to specify a constraint boundary, and hence constraint areas. For each of these areas, the generation adequacy is assessed in order to identify the capacity required to satisfy the LOLE requirement. This minimum capacity requirement per area would represent the lower bound of their minimum MW requirement;

- A detailed transmission network capacity assessment is carried out on the meshed transmission system (should the high level assessment above not identify a constraint); or on the resulting non-meshed systems (should the high level assessment above identify a constraint). The purpose is to test the meshed system's compliance with the TSSPS for a range of plausible cases. The purpose of the assessment is to identify network capacity constraints which limit power transfer and for which generation in an area would be required to mitigate those constraints. This is carried out using AC load flow simulations and considering only those constraints that are related to power transfer.

Based on the results of the locational capacity assessment, the constraint areas are identified and a minimum MW per constraint area is calculated. This is described as follows:

- If the All-Island transmission system is deemed not to be meshed by the high level assessment, then each non-meshed area would represent a Level 1 Locational Capacity Constraint Area. The minimum MW for of these Level 1 non-meshed areas is then calculated by assessing the generation adequacy per area. This is consistent with the approach undertaken in the Generation Capacity Assessment and the All-Island Capacity Requirement methodology.

- Further constraint area(s) are identified by analysing the results of detailed transmission network assessments. Locational Capacity Constraint Areas are identified by:

- Considering the location of the transmission network constraints;
- Assessing the driver of the constraint (e.g. thermal overload of equipment; or the lack of transmission network capacity to accommodate the power flow); and
- Assessing whether the constraints would be resolved by constraining on more capacity in the area.

- The minimum MW required for each constraint area is determined by calculating the amount of MW needed to mitigate the identified constraints. This is accomplished by taking the load flow tests that have identified constraints and using that level of capacity within the constrained area as the starting point. The level of capacity within the identified area is iteratively increased and the load flow tests are repeated until the Transmission System Security and Planning Standards are met.

- The methodology outputs are then compiled by consolidating the results of the above analysis to define a level, the corresponding area boundary and the Transmission System Security and Planning Standards in each Locational Capacity Constraint Area.

5 Description of Methodology Components

The methodology comprises a number of components as described in the outline of the methodology above. Each of these components is described in more detail below:

5.1 Inputs

The methodology inputs are taken from the data sources discussed above. This section details what information is taken from the data sources and what assumptions are made to generate the inputs that are used in the analysis.

5.1.1 Demand

The demand forecasts are taken from the latest Generation Capacity Statement. The Generation Capacity Statement sets out a range of demand forecasts for future years.

The Capacity Requirement and De-rating Factor methodology and the Locational Capacity Constraints methodology both use the same demand forecasts. Both methodologies make use of the range of demand levels between the low and the high forecasts.

For the first auction, demand forecasts from the Generation Capacity Statement 2017-2026 will be used in both methodologies. The Capacity Requirement for the first auction will be based on the demand forecast for the 2021/22 Capacity Year.

The Ten Year Transmission Forecast Statement (TYTFS) describes the methodology for forecasting transmission station demand and the individual transmission station demands are listed in the appendices. The TYTFS takes account of regional demand growth, including domestic, industrial and data centre load, which is reflected in the transmission station loads. Figure 3 provides an illustration of the approach used for setting up the demand data for the detailed network assessments. For illustration the following steps were performed for the first auction:

1. The location of demand at transmission nodes are tabulated in the annual forecast statement (TYTFS 2016-2025):
    a. The process for allocating demand to each transmission node is contained in the TYTFS 2016-2025 (Chapter 3).
    b. The TYTFS 2016-2025 was developed using GCS 2016-2025. This was the most current GCS at the time.

2. For the Locational Capacity Constraint analysis the peak demand figures are taken from the most recent GCS (GCS 2017-2026). This aligns with the all-island Capacity Requirement and De-rating Factor Analysis.
3. Additional nodes were added to the 2018 network to align with the forecasted demand centre growth in GCS 2017-2016. These nodes are not currently part of the network, but are required to align with the demand forecast year (2021/22). This step may not be required for all auctions.
4. The updated network is combined with the demand forecast from the most recent GCS to produce the demand distribution for the detailed network assessments
5. The detailed network analysis is then performed for a range of demand levels from low to high.

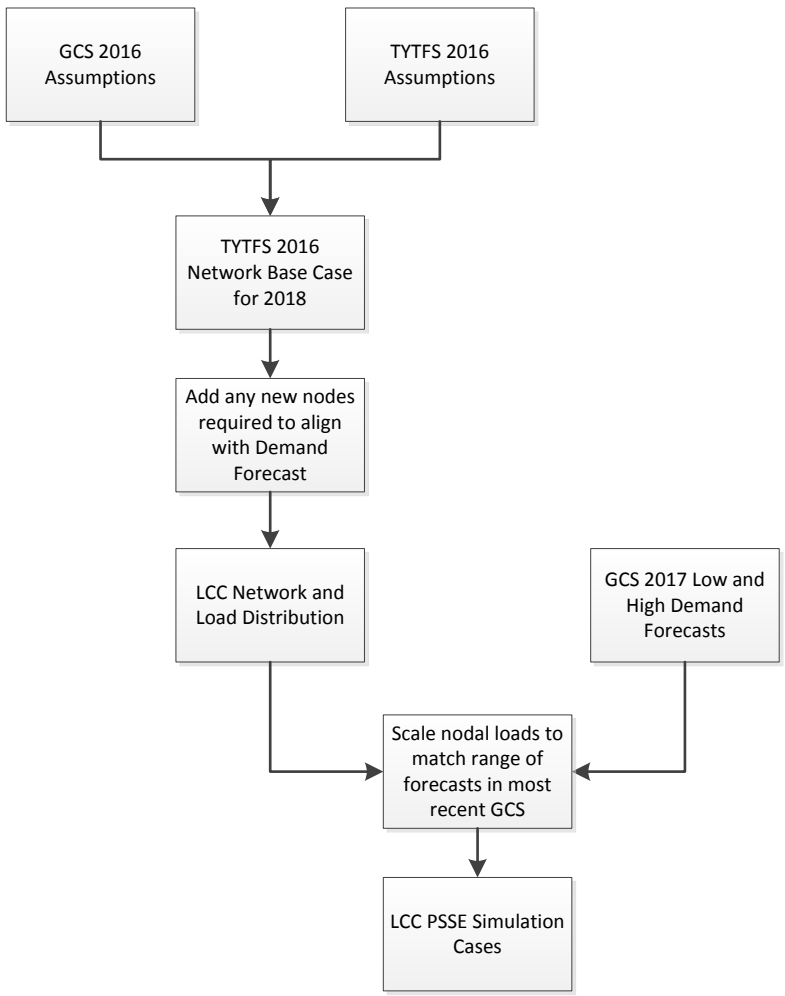


Figure 3 Illustration of the approach taken for setting up the demand data for the Locational Capacity Constraints detailed network assessments (this references the Generation Capacity Statements and Transmission Forecast Statement used for the first auction. The most recent documents will be used for each auction)

5.1.2 Transmission Network

The transmission system in Northern Ireland is operated at 275 kV and 110 kV. The transmission system in Ireland is operated at 400 kV, 220 kV and 110 kV. The two transmission systems are connected by means of one 275 kV double circuit (i.e. the 1st North South tie line). EirGrid and SONI together operate the transmission systems - North and South - on an all-island basis. The map[5] of the transmission system is shown in Figure 4 below.

The network to be assessed is derived from the TYTFS. For the T-1 Capacity Market Auctions the transmission network used will consist of the network existing at the date of calculation. Operational logic used to manage circuit and equipment loading is taken into account in the simulations. If Locational Capacity Constraints are to be included in the T-4 Capacity Market auctions special consideration may need to be given to changes to the transmission infrastructure whose timing is likely to have a significant impact on network constraints.

[5] http://www.eirgridgroup.com/site-files/library/EirGrid/EirGrid-Group-Transmission-System-Geographic-Map-Sept-2016.pdf

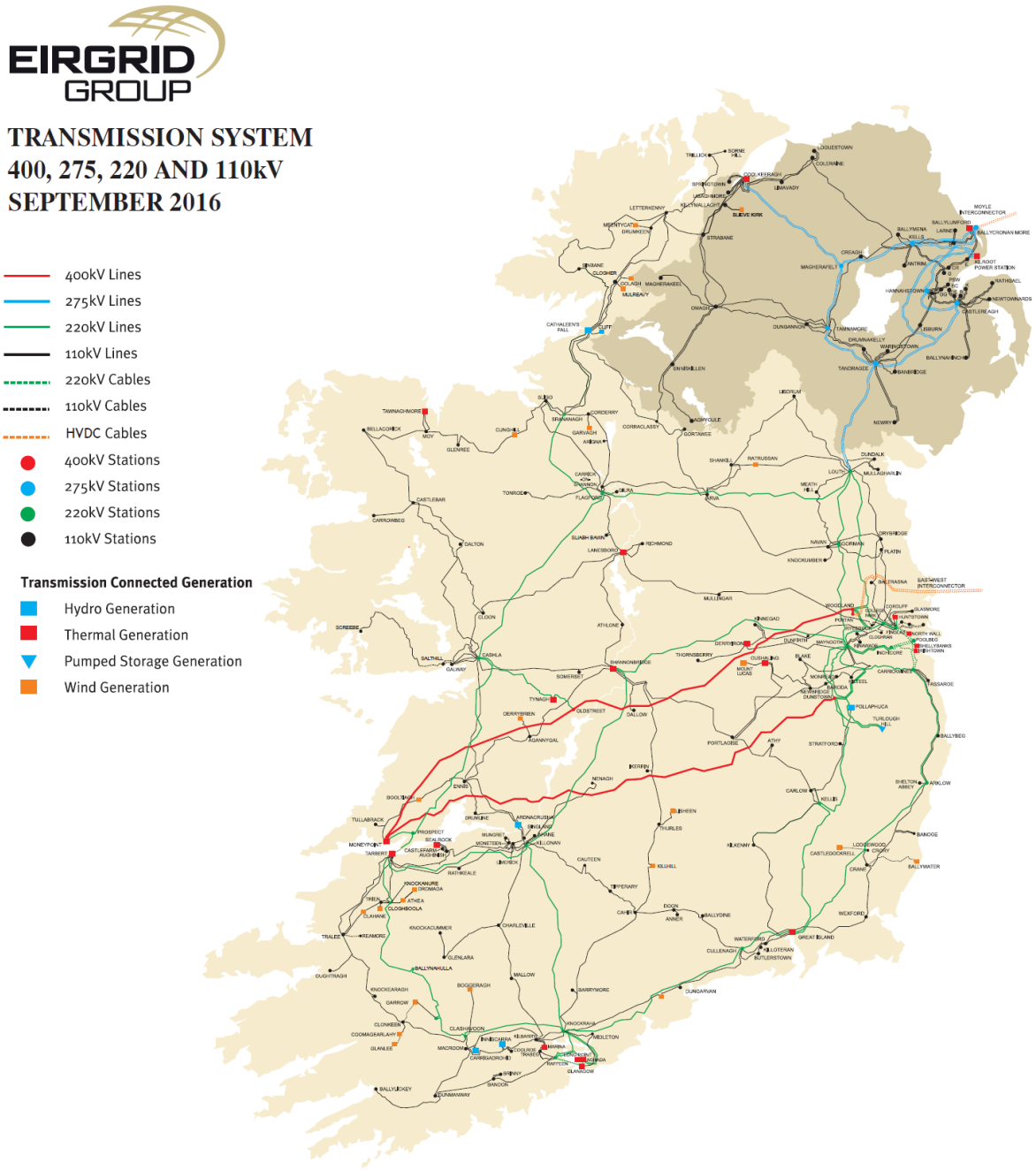


Figure 4: Map of the transmission system on the Island of Ireland (September 2016).

5.1.3 Portfolio

The same portfolio of capacity providers that is used for the Capacity Requirement and De-Rating Factor calculation is used. This in turn is based on the portfolio of plant listed in the Generation Capacity

Statement adjusted for any known new plant or plant closures that would occur prior to the start of the Capacity Year being studied.

The level of installed wind generation is taken from the Generation Capacity Statement and the level that is forecast to be installed at the start of the Capacity Year to be studied. The level of installed interconnection is also taken from the Generation Capacity Statement and the level that is forecast to be installed at the start of the Capacity Year to be studied. Currently only the Moyle Interconnector and the East West Interconnector (EWIC) are included, but the same principles will apply to future interconnection.

For the purpose of the network assessments units are assumed to remain connected at the nodes at which they are currently connected.

5.2 Locational Capacity Assessment

This section describes the analysis components necessary to identify transmission capacity constraints.

The transmission network is designed to be meshed to provide a high level of reliability. The meshed nature of the transmission network allows for the outage of items of plant without detrimentally impacting on the continuity of electricity supply. The standard to which the network is required to be designed is described in the TSSPS.

Notwithstanding this, there are cases where there are radial connections (i.e. single circuits to connect a remote node), but this is typically to connect generators or small loads to the meshed system. For the purpose of this analysis radial connections are not considered as local constraints.

The capacity assessment consists of the following:

5.2.1 High Level Network Topology Assessment

The purpose of the high-level transmission network topology assessment is to identify the extent to which the all-island transmission system is meshed.

The unconstrained market simulation assumes that the transmission network does not impose a constraint. Therefore, where the all-island transmission system is not capable of complying with the most fundamental security of supply requirement (i.e. single contingency capability) it is possible to define a transmission network constraint. Depending on the location of such constraints within the all-island transmission system, it is possible to specify a boundary for the non-compliant systems.

High level assessment of transmission system topology involves the following:

- In applying the TSSPS to the all-island transmission system, in the absence of the second North-South the NI and IE systems are not meshed as they do not comply with the contingency capability requirements on an all-island basis. This means that the outage of the existing 275kV link between NI and IE would lead to the separation of the two transmission systems. This is a transmission system constraint; and

- The transmission constraint arising from the non-meshed all-island system has implications for the assessment of capacity requirements discussed above, i.e. NI and IE need to be assessed separately.

5.2.2 Area LOLE Adequacy Assessment

A LOLE adequacy assessment will be performed for the non-meshed areas discussed above (currently NI and IE). A similar adequacy assessment approach to that used in the all-island Capacity Requirement analysis will be used.

To perform this type of an assessment the following information is required: a clearly defined area, the reliability of existing and potential new capacity in the area and quantification of the reliance on external areas and markets. This approach has the benefit of being aligned with the all-island Capacity Requirement methodology and assumptions.

Capacity adequate portfolios (portfolios that satisfy the adequacy standard) are created for each non-meshed area based on the LOLE adequacy standard. This will use the same portfolio and demand assumptions as the all-island assessment, but will use the demand forecasts and profiles and capacity portfolios that apply to the relevant non-meshed areas. A number of capacity adequate portfolios will be calculated for each area and demand scenario.

To convert from real capacity to de-rated capacity, the capacity of the units in the capacity adequate portfolios are multiplied by their respective de-rating factors. For consistency, the de-rating factors that will be used by units in qualification will be applied. This gives the quantity of de-rated capacity that will be required in each area to satisfy the adequacy standard in that area for each demand scenario.

The Least-Worst Regrets analysis in the Capacity Requirement and De-rating Factor methodology will pick the demand scenario for the Unconstrained Auction Capacity Requirement as set out in SEM-16-082. It is proposed that the same demand scenario will be used for the IE and NI locational

constraint area requirements. That is, once the least-worst regrets analysis has picked the demand scenario for the auction, this will identify which one of the area capacity requirements calculated above will be used for the locational area constraints methodology.

The SEM has an 8 hour LOLE adequacy standard and this standard will be used to calculate the All-Island Capacity Requirement. An 8 hour LOLE standard is also used for each non-meshed area.

5.2.3 Detailed Network Capacity Assessment

The detailed network capacity assessment is carried out to identify transmission network constraints and is carried out using AC load flow simulations[6]. Such simulations analyse the steady state power flow for a given stable network situation. Although the analysis considers both real and reactive power flow, the focus of these simulations is limited to the analysis of capacity-constrained situations only.

Overview

An illustration of the detailed network capacity assessment is shown in Figure 5.

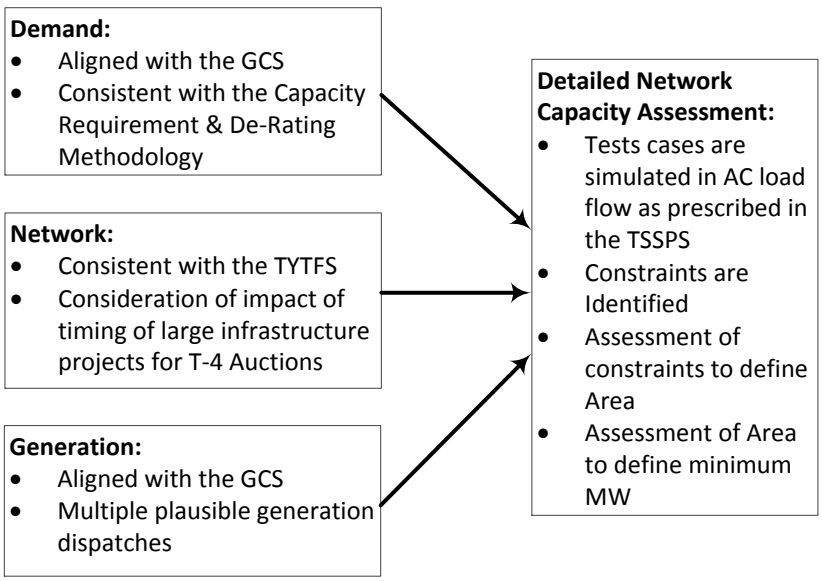


Figure 5: Illustration of Methodology for carrying out detailed network capacity assessment

[6] The AC load flow simulations are conducted using PSS®E

Figure 5 shows the three main inputs required for carrying out a detailed network capacity assessment, namely: the demand; the network; and generation. These are described as follows:

- *Demand*:

  As outlined in Section 5.1.1 above, the peak demand is taken from the GCS. The allocation of the total peak demand to each of the transmission stations is derived from the TYTFS where the regional growth rates, considering domestic, industrial and data centre loads is accounted for.

  Multiple cases of demand within the range from the low to the high forecast are considered in the preparation of test cases, which is consistent with the Capacity Requirement and De-Rating Methodology. These multiple demand cases for the selected year are used to assess the capacity constraints associated with the transmission network.

- *Network*:

  The transmission network as described in the TYTFS for the selected year is used in the simulations. The network includes all planned or scheduled reinforcements as described in the TYTFS. The applicable line and cable ratings are used.

- *Generation*:

  A large number of portfolios are created to represent as broad a range of possible auction outcomes, for which a range of dispatches are created to meet the demand range between the low and high demand forecast described in the GCS. The generation dispatches reflect the possible range of conventional generation, import or export on the interconnectors and the level of wind generation for the respective study year.

Modelling the Power System

The power system is modelled by relating a demand case with a corresponding generation dispatch pattern and simulating the resulting power flows through the transmission system. In such a way, each generation dispatch profile corresponds with a demand case (referred to above) in order to create a test case, creating multiple test cases for which the transmission network is tested. These test cases will account for the anticipated operation of the network for the year of study.

The intention of creating multiple test cases is to account for the broad range of plausible generation and demand combinations that may occur on the system. For each of these plausible cases, the transmission network is required to be capable of accommodating the resultant power flows that occur.

The test cases account for differing generation dispatch patterns and their corresponding maximum demand; import or export on the interconnectors; and the level of wind generation for the respective study year.

Identifying Capacity-Related Constraints

Each test case is checked for compliance with the TSSPS. A full assessment of transmission network contingencies is carried out for each test case using AC load flow analysis. This involves assessing the impact of an outage of each transmission circuit and item of equipment, and therefore involves thousands of contingencies being tested.

If the test case is compliant then this indicates the network is sufficient for the generation dispatch and the demand represented in the test case. If the test case is not compliant with the TSSPS then these test cases potentially identify capacity-related transmission network constraints and are further analysed.

5.3 Methodology Outputs

The SEM Committee Decision Paper (SEM-16-081, 8 December 2016) describes the required representation of the locational capacity constraint areas and minimum MW requirements. This methodology is designed to satisfy this required representation. The following two tables illustrate the format in which results will be presented

Table 1: *Level 1* Locational Capacity Constraint Areas and Corresponding Minimum MW for Capacity Year:

Level	Locational Capacity Constraint Area Name	Associated Level 2 Locational Constraint Area	Locational Capacity Constraint Area Nodes	Minimum MW[7] per Locational Capacity Constraint Area
1	L1-1:	-		
1	L1-2:	L2-1:		

[7] Minimum MW represented in de-rated GW values

Table 2: *Level 2* Locational Capacity Constraint Areas and Corresponding Minimum MW for Capacity Year:

Level	Locational Capacity Constraint Area Name	Associated Level 1 Locational Constraint Area	Locational Capacity Constraint Area Nodes	Minimum MW[8] per Locational Capacity Constraint Area
2	L2-1:	L1-2:	The following high voltage nodes: 1.	

5.3.1 Identification of Constraint Areas

The areas are identified based on the locational capacity assessment explained in 5.2. Up to two levels of transmission capacity constraint areas can be considered.

The results of the constraint analysis will inform how the constraint areas are allocated to their respective levels, respecting that there are no more than two levels and that the constraint areas may be nested.

Note that in the event that no non-meshed Level 1 areas are identified by the high-level network assessment, the area(s) identified by the detailed network assessments would then be Level 1 areas.

Non-Meshed Constraint Areas

A high level assessment of transmission system topology is used to assess the extent to which the all-island transmission system is meshed and hence for which the TSSPS would apply (see Section 5.2.1).

Where the transmission system is not capable of complying with the most fundamental security of supply requirement (i.e. single contingency capability) it is possible to define a boundary for the non-compliant systems.

Where such a constraint exists, this would represent the first Level of constraints where the areas would be defined as those on either side of the constraint.

Meshed Constraint Areas

[8] Minimum MW represented in de-rated GW values

Detailed network capacity assessment is carried out to define a boundary for a constraint area of the transmission system (see Section 5.2.3). The purpose of the assessment is to identify network capacity constraints which limit power transfer and for which generation in an area would be required to mitigate those constraints.

A detailed network capacity assessment is carried out for multiple test cases and their contingencies. The constraint area(s) are identified by analysing the results of detailed network capacity assessment. Locational Capacity Constraint areas are identified by:

- Assessing the driver (i.e. the type of contingency, and the item of equipment such as a circuit, transformer etc.) causing the constraint; and the type of constraint (e.g. thermal overload of equipment, or the lack of transmission network capacity to accommodate the power flow) on the network;

- Assessing the location of the transmission network constraint. The locations of the identified constraints for the range of test cases are used to define the boundary of the potential locational constraint area; and

- Assessing whether the constraints would be resolved by constraining on more capacity in the area. Therefore, only nodes where additional capacity at that node will alleviate all or most of the identified constraint are considered to be in the constraint area in the context of this analysis. If the area constraint relates to getting power out of an area and is alleviated by reducing generation in the area the constraint is not part of the scope of this work.

The constraints analysis is focused on the transmission network and seeks to define the transmission nodes that are contained within the Locational Constraint Area. Where distribution nodes are identified in the Constraint Area, they are done in order to: (a) clearly identify all nodes in the constraint area; and (b) identify any generation that can contribute to mitigating the transmission constraint.

In order to be included in a Locational Capacity Constraint Area, the Capacity Market Unit must be wholly within the defined constraint area. All generator units/generator demand sites associated with demand side units must be directly connected to the transmission system node listed in the Locational Constraint Area; or distribution system node at a point normally connected to one of the transmission system nodes in the Locational Capacity Constraint Area.

5.3.2 Calculation of Minimum MW per Constraint Area

Non-Meshed Constraint Areas

The high level assessment of the transmission system topology will identify areas of the all-island transmission system that are not meshed. These areas would not be compliant with the planning standards in Ireland and Northern Ireland (see Section 5.2.1) and a minimum amount of generation may be defined for each of the resulting non-meshed constraint areas. If such areas exist they would represent Level 1 constraint areas. The LOLE assessment (Section 5.2.2) would then set the lower bound of the MW requirement in each of these areas. As discussed above, this is determined by calculating the de-rated capacity required to satisfy the adequacy standards in each area for the demand scenario selected by the least-worst regrets analysis.

Meshed Constraint Areas

Detailed network analysis described in Section 5.2.3 is used to identify the minimum MWs for each of the subsequent constraint areas that are identified.

The minimum MW is determined by testing the required levels of generation necessary to mitigate the identified transmission network constraints. This is quantified though additional power flow simulations, where the simulations take the non-compliant cases and increase the generation within the identified area until the constraints are alleviated. Different constraints are more onerous for different test cases and that the analysis will seek to ensure that the TSSPS is met for each of those test cases.

To determine the minimum MW required to mitigate constraints, the demand range between the low and high demand forecasts described by the GCS is divided into a number of sub-ranges. This aligns with the approach used for the all-island Capacity Requirement calculation and the Locational Capacity Constraint Level 1 LOLE analysis. The demand sub-range that most closely aligns with the least-worst regrets demand level (refer to the Capacity Requirement methodology) is used to calculate the Minimum MW Requirement in the detailed network assessments.

The assessment for the constraint areas is performed for all demand levels. The Minimum MW Requirement is calculated by iteratively adding generation to the area until the constraints are resolved for the demand level most closely aligned to the all-island Least-Worst Regrets demand level.

6 Conclusion

The approach uses existing tools, transmission system standards and models; and makes use of prevailing data sources. Where appropriate, the methodology uses the same approach and assumptions used to calculate the All-Island Capacity Requirement. Similarly, the approach is consistent with that used to identify transmission network constraints and their corresponding reinforcements as detailed in the All-Island Ten Year Transmission Forecast Statement.

The methodology detailed in this document has been designed to be objective and systematic. It is based on computational rigour.

This document sets out the methodology that the TSOs use to determine the locational capacity constraints for the Capacity Market. The methodology combines existing network planning and generation adequacy tools and standards into a framework that can fulfill the requirements set out in SEM-16-081.

The methodology focuses on power transfer constraints only. Safe and secure operation of the power system will continue to require investment in ancillary services which is not addressed as part of this scope of work.