Policy Statement on Busbar Configuration for 110 kV, 220 kV and 400 kV Transmission Substations

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<th>Pol_St_3_Busbar_Configuration</th>
<th>Applicable to: Ireland</th>
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<tr>
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<td>Category: Substations</td>
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Introduction

This policy provides a set of practical rules for Busbar configuration design for all new, existing and planned 110 kV, 220 kV and 400 kV transmission substations. The default standard Busbar configuration is the Enhanced Ring Busbar for new transmission substations and, where feasible, existing and planned substations. The C-Type Busbar configuration is the initial phase for the Enhanced Ring Busbar configuration.

The objective is to deliver a consistent approach to the design and operation of transmission substations in Ireland while ensuring a safe, secure, reliable and efficient transmission power system, delivered in an economic manner. This is achieved by ensuring an adequate level of transmission substation reliability, and by extension consistent system-wide reliability, while ensuring that investment decisions maintain or improve reliability where required.

Over the life-cycle of a transmission substation, based on cost, reliability, operational flexibility and maintainability, the Enhanced Ring Busbar configuration is a more effective solution than a single Busbar configuration. When compared with a double Busbar configuration, the Enhanced Ring Busbar offers a greater level of reliability and flexibility for a similar cost. Furthermore, the ring topology of the Enhanced Ring Busbar offers the advantage of increased asset utilisation, in particular for circuits with high thermal ratings (e.g. HTLS), better substation through-flow capability and hence better overall system reliability.

The Enhanced Ring Busbar also supports modular development, as a C-Type Busbar can be constructed when four or less HV Bays are required. Depending on technology, the C-Type Busbar includes two Sectionaliser Disconnectors or two Sectionaliser Bays to minimise operational disruption and/or construction for expanding to an Enhanced Ring Busbar configuration.
**Definitions**

| **Busbar** | Consisting of one or more **Busbar Sections** which are designated ‘A’ in single **Busbar** substations (Figure 1) and ‘A’ and ‘B’ in double **Busbar** substations (Figure 2). |
| **Busbar Section** | A **Busbar** consists of one or more **Busbar Sections** which are connected together, e.g. with a **Sectionaliser Bay** or **Sectionaliser Disconnector**. For example a **C-Type Busbar** configuration consists of two **Busbars** (A and B) with one **Busbar Section** (A1 and B1) on each **Busbar**. |
| **C-Type Busbar** | A **C-Type Busbar** configuration (Figures 3a and 3b) is the initial phase of an **Enhanced Ring Busbar** configuration which includes:  
  - Two **Busbars**, each with one **Busbar Section**.  
  - Up to:  
    - Four **HV Bays** for a meshed substation, and  
    - Six **HV Bays** for a radial substation, and  
  - One **Wing Coupler**.  
  - One **Sectionaliser Bay** consisting of:  
    - Two **Sectionaliser Disconnectors** for AIS.  
    - Four **Sectionaliser Disconnectors** and two **Circuit Breakers** for GIS.  
  - Provision that the technology used can be expanded to an **Enhanced Ring Busbar**. |
| **Circuit Breaker** | A mechanical switching device capable of making, carrying, and breaking current under intact and contingency operating conditions. |
| **Coupler** | A **Coupler** is used in a substation (typically double **Busbar** substations) to couple the A and B **Busbars**. A **Coupler**-consists of a **Circuit Breaker** and a combination of **Busbar Disconnectors** and **Sectionaliser Disconnectors**. **Couplers** can vary in design and can have varying numbers of **Busbar** and **Sectionaliser Disconnectors**. |
| **Busbar Disconnector** | A switch that connects or disconnects a **HV Bay** to the A and B **Busbars**. |
| **Enhanced Ring Busbar** | A **Busbar** configuration (examples in Figures 2 and 3) that includes:  
  - A double **Busbar** configuration formed as a closed loop with **Sectionaliser Bays** and **Wing Couplers** in series.  
  - A minimum of four (e.g. A1, B1, A2 and B2) **Busbar Sections**.  
  - Two **Wing Couplers**.  
  - A minimum of two **Sectionaliser Bays**.  
  - A maximum of:  
    - Four **HV Bays** per **Busbar Section** for a meshed substation, e.g. a maximum of four **HV Bays** connected |
to the both A1 and B1 Busbar Sections.
- Six HV Bays per Busbar Section for a radial substation.
- An even distribution of circuit and transformer bays per Busbar Section where feasible.

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<tr>
<th>HV Bay</th>
<th>Any bay (e.g. for a transformer, overhead line, underground cable, capacitor bank etc.) that is directly connected to the substation Busbar. A single bay substation may have a HV Bay but not a Busbar. A HV Bay does not include a bay used for equipment that couples Busbars or Busbar Sections such as Couplers, Wing Couplers or Sectionaliser Bays.</th>
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<tr>
<td>Largest Credible Generation Infeed</td>
<td>Defined as the single largest generation unit or interconnector connected to Ireland’s transmission system as defined in the most recent All-Island Transmission Forecast Statement.</td>
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<tr>
<td>Non-Standard Configuration</td>
<td>The exception to Standard Configuration is where the Non-Standard Configuration is employed to facilitate the connection and testing of new infrastructure or plant. The Non-Standard Configuration shall only be considered for planned or forced outages permissible under the EirGrid Transmission Planning Criteria (TPC) to permit maintenance, or following a forced outage, of one item of plant and equipment rather than for unusual generator patterns.</td>
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<tr>
<td>Sectionaliser Bay</td>
<td>Consisting of a Circuit Breaker with two Sectionaliser Disconnectors connecting two Busbar Sections on the same Busbar (e.g. connecting A1 to A2).</td>
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<tr>
<td>Sectionaliser Disconnector</td>
<td>A switch that connects or disconnects two Busbar Sections, e.g. A1 and A2.</td>
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<td>Skeleton Bay</td>
<td>An unequipped future bay i.e. space for a future bay with no switchgear provided.</td>
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<td>Standard Configuration</td>
<td>The Standard Configuration of all 110 kV, 220 kV and 400 kV substations shall permit all HV Bays and equipment to be maintained. The Standard Configuration shall have Busbar Sections connected using either Sectionaliser Bay or couplers. Standard Configurations (currently single Busbar, double Busbar, C-Type Busbar, Enhanced Ring Busbar or breaker and a half substations) shall be the same for all 110 kV, 220 kV and 400 kV substations to reduce the possibility of operator error.</td>
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<td><strong>System Generation</strong></td>
<td>Defined as the generation required to balance the <strong>System Load</strong>.</td>
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<td><strong>System Load</strong></td>
<td>Defined as Ireland’s forecasted transmission system peak load as detailed in the most recent All-Island Generation Capacity Statement.</td>
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<tr>
<td><strong>System Transformers</strong></td>
<td>Transformers used to connect transmission voltage levels (e.g. 400/220 kV, 400/110 kV, 220/110 kV or 220/275 kV).</td>
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<tr>
<td><strong>Wing Coupler</strong></td>
<td>Consisting of a <strong>Circuit Breaker</strong> with two <strong>Sectionaliser Disconnectors</strong> connecting two <strong>Busbars Sections</strong> on different <strong>Busbars</strong> (e.g. connecting A1 to B1 in Figures 3a, 3b, 4 and 5 or A2 to B2 in Figure 4).</td>
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**Figure 1: Single Busbar Configuration**

**Figure 2: Double Busbar Configuration**

**Figure 3a: Four Bay C-Type AIS Busbar Configuration**

**Figure 3b: Four Bay C-Type GIS Busbar Configuration**
Policy & Principles

There are two main categories of transmission substations defined in this policy:

1. New transmission substations, and
2. Existing and planned transmission substations.

Section 1 shall be considered for new transmission substation works and Section 2 shall be considered for existing and planned transmission substation works.

A substation can be defined as either existing or planned by meeting one or more of the following criteria:

i. A radial or meshed 110 kV, 220 kV or 400 kV substation that is already constructed and/or connected to the transmission system.

ii. Has a detailed **Busbar** configuration specified in a connection offer executed by both EirGrid and the customer

iii. Has a modification request to a connection offer (or a change to a related project) that does not result in a change to the **Busbar** configuration.
There are other busbar configurations on the system such as the reduced ring Busbar in the Galway 110 kV substation and the breaker-and-a-half Busbar in the Shellybanks 220 kV substation. This policy considers the Galway Busbar to be a single Busbar and the Shellybanks Busbar to be a double Busbar.

Substation connectivity to the transmission system is defined as being either radial (a single or tail connection) or meshed (at least two connections). A meshed substation has the same connectivity to the transmission system as a looped substation.

1. **New Transmission Substations**

This section of the policy outlines the minimum requirements for new 110 kV, 220 kV and 400 kV transmission substations.

1.1. A radial transmission substation which requires:

   1.1.1. A single HV Bay may be designed without a Busbar.²

   1.1.2. Between two and six HV Bays shall be designed with a C-Type Busbar configuration.

   1.1.3. More than six HV Bays shall be designed with an Enhanced Ring Busbar configuration.

1.2. A meshed transmission substation with one voltage level that requires:

   1.2.1. Up to four HV Bays shall be designed with a C-Type Busbar configuration.

   1.2.2. More than four HV Bays shall be designed with an Enhanced Ring Busbar configuration.

1.3. A meshed transmission substation with two or more transmission voltage levels³ that requires:

   1.3.1. Four HV Bays or less per transmission voltage level shall be designed with a C-Type Busbar or Enhanced Ring Busbar configuration at each voltage level with a maximum of two System Transformers permitted to connect the transmission voltage levels.

   1.3.2. More than four HV Bays per voltage level shall be designed with an

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¹ There are other busbar configurations on the system such as the reduced ring Busbar in the Galway 110 kV substation and the breaker-and-a-half Busbar in the Shellybanks 220 kV substation. This policy considers the Galway Busbar to be a single Busbar and the Shellybanks Busbar to be a double Busbar.

² This may be impractical and not possible for GIS substations.

³ E.g. 400/220 kV, 400/110 kV, 220/110 kV or 400/220/110 kV
Enhanced Ring Busbar configuration for each voltage level with a maximum of four System Transformers permitted to connect two transmission voltage levels.

1.4. A radial or meshed transmission substation with two or more transmission voltage levels may have a combination of C-Type Busbar and Enhanced Ring Busbar configurations assuming HV Bay requirements in Sections 1.1 and 1.2 are met.

1.5. For a C-Type Busbar configuration, the technology used shall facilitate the safe expansion, with minimal operational disruption, to an Enhanced Ring Busbar configuration:

1.5.1. An AIS transmission substation shall be laid out in a manner which includes two Sectionaliser Disconnectors (Figure 3a) on each Busbar.
1.5.2. A GIS transmission substation shall be laid out in a manner which includes a full Sectionaliser Bay (Figure 3b) on each Busbar.

2. Existing and Planned Transmission Substations

This section of the policy outlines the rules for the busbar configuration at existing and planned transmission substations. Where stated, the Busbar Configuration Guide\(^4\) may be used as a case-by-case busbar configuration assessment methodology.

2.1. The replacement or refurbishment of a transformer (or associated transformer bay equipment) at an existing or planned transmission substation, with an equal or higher MVA rating and does not drive the need to uprate the Busbar, may not drive a change from the Busbar configuration at the substation.

2.2. A transmission substation without a Busbar, that requires the connection of an additional HV Bay, shall be designed as a C-Type Busbar or Enhanced Ring Busbar depending on the rules outlined in Sections 1.1 and 1.2.

2.3. A transmission substation with a C-Type Busbar configuration with less than four HV Bays, that requires one additional HV Bay, may remain as a C-Type Busbar transmission substation.

2.4. If technically viable\(^5\), a transmission substation with a C-Type Busbar configuration for each voltage level with a maximum of four System Transformers permitted to connect two transmission voltage levels.

\(^4\) http://gridshare/sites/FG/A_P/Policies/Substations/Busbar%20Configuration/PoI_St_3_Busbar_Configuration/Issue%203%20-%202015_v3.0/Busbar_Configuration_Policy_Guide_v1.docx

\(^5\) This refers specifically to GIS technology which, due to the age of the equipment, may not be expandable.
configuration and four HV Bays, which requires an additional HV Bay, shall be expanded and designed as an Enhanced Ring Busbar configuration. Otherwise the Busbar Configuration Guide shall be used to determine the Busbar configuration.

2.5. The Busbar Configuration Guide shall be used to determine if an additional HV Bay, a replacement HV Bay, a Busbar uprate, or a substation refurbishment drives the requirement for migration to a C-Type Busbar or Enhanced Ring Busbar configuration at a transmission substation with four or more HV Bays.

2.6. For a transmission substation with a single Busbar configuration, a new HV Bay may connect temporarily to the existing Busbar in advance of the associated C-Type Busbar or Enhanced Ring Busbar being constructed.

3. General Substation Considerations

This section of the policy outlines additional considerations, irrespective of the substation being classified as new, existing or planned.

3.1. A Busbar Section shall have no more than:
   3.1.1. Four HV Bays for a meshed substation, and
   3.1.2. Six HV Bays for a radial substation.

3.2. Sections 4.1 and 4.2 of the Transmission Planning Criteria\(^6\) shall be complied with when considering substation Busbar configuration works.

3.3. New GIS meshed transmission substations shall not be designed as single Busbar configurations.

3.4. GIS technology, by its nature, does not lend itself to Skeleton Bays. However GIS substations can be extended, e.g. a C-Type Busbar substation can be converted into an Enhanced Ring Busbar configuration, even by a different switchgear manufacturer.

3.5. Future GIS bays can be added via Busbar extension and not via provision of skeleton bays. Wing Couplers shall be relocated where required. GIS building sizes shall consider station extendibility on a project-by-project basis. Service continuity requirements are captured in the latest version of the EirGrid GIS functional specification, XDS-GFS-25-001.

3.6. GIS spare bays should only be fully equipped where it is envisioned that they will be required based on plans outlined in the latest national Transmission

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3.7. 110 kV, 220 kV and 400 kV transmission substations shall not use XLPE cable. Solid tubular Busbars or stranded conductor shall be used for AIS Busbars. Gas insulated bus duct shall be used for GIS stations.

3.8. The loss of any 110 kV transmission Busbar Section operated in Standard Configuration shall not directly or indirectly result in the loss of more than 250 MW of System Load or the equivalent MW quantity of System Generation.

3.9. The loss of any 110 kV transmission Busbar Coupler or Sectionalising Bay (e.g. two Busbar Sections) shall not directly or indirectly result in the loss of more than 500 MW of System Load or the equivalent MW quantity of System Generation.

3.10. The loss of any 220 kV or 400 kV Busbar Section operated in Standard Configuration shall not directly or indirectly result in the loss of 250 MW of System Load or System Generation exceeding the rating of the single Largest Credible Generation Infeed permissible on the system.

3.11. The loss of any 220 kV or 400 kV Busbar Section or HV Bay in Standard Configuration shall not result in the cascade tripping of any other part of the transmission system.

3.12. The loss of any 220 kV or 400 kV Busbar Disconnector, Coupler or Sectionaliser Bay shall not directly or indirectly result in the loss of more than 500 MW of System Load or System Generation exceeding twice the rating of the single Largest Credible Generation Infeed permissible on the system.

3.13. With the exception of Section 3.11, regarding Busbar Disconnectors, Couplers or Sectionaliser Bays, the loss of any 220 kV or 400 kV section of busbar operated in Non-Standard Configuration shall not directly or indirectly result in the loss of more than 375 MW of System Load or System Generation exceeding the rating of the single Largest Credible Generation Infeed permissible on the system.

Application

This policy applies to all new, existing and planned 110 kV, 220 kV and 400 kV transmission substations in Ireland.

With regards to existing transmission substations, this policy acknowledges the historical development of each substation and the present Busbar configurations are therefore deemed to satisfy performance requirements to date. Should the needs of an existing substation change or the substation be redeveloped (including...
expansion and the replacement of equipment) this policy shall therefore apply.

**Derogation**

Exception from the minimum requirements outlined in this policy can only be achieved by applying the *Derogation Policy*.

**Revision History**

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<tr>
<th>Version</th>
<th>Date</th>
<th>Summary of Changes/ Reasons</th>
<th>Authors</th>
<th>Approved By</th>
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<tr>
<td>v1.0</td>
<td>2009</td>
<td>Original Busbar Policy</td>
<td>Jon O’Sullivan, Mark Norton</td>
<td>Andrew Cooke, Fintan Slye</td>
</tr>
<tr>
<td>V2.1</td>
<td>2013</td>
<td>Updated to, based on legal review, to reflect the EirGrid busbar position paper [<em>1</em>]</td>
<td>Mario Duarte, Jeff Kelliher</td>
<td>Andrew Cooke, John Fitzgerald</td>
</tr>
<tr>
<td>V3.0</td>
<td>2015</td>
<td>Updated to address high number of derogations for existing substations</td>
<td>Yvonne Coughlan, Jeff Kelliher, John Leahy</td>
<td>Transmission Investment Committee (TIC)</td>
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**References**

[1] Position Paper – Proposed Move from Existing Double Busbar Station Philosophy to a New Enhanced Ring Station Philosophy [2010]