Policy on Calculation of the Maximum Fault Level for Substation Earth Grid Design

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Policy Owner: PST	**Policy Category:** Earth Grid
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Background

One of the most important parameters for the design of a substation earth grid is the maximum earth fault current that could arise under fault conditions. This is the current that will need to be dissipated to remote earth and will result in the highest Grid Potential Rise (GPR) in and around the substation. This parameter enables the earth grid to be designed so that worst case step and touch voltages are limited to below human body tolerable limits as defined by IEEE80-2000 [1].

EirGrid is responsible for providing the design earth fault current to customers constructing a transmission substation on a contestable basis, or to the TAO for non-contestable substation builds or extensions.

This document details the policy for the calculation of the maximum earth fault current for substation earth grid design. It does not purport to be the totality of the design of an earth grid.

In accordance with the latest version of the Earthing and Lightning Protection specification [2] the entire earthing system[1] shall be tested upon completion to verify compliance with the specifications and design parameters.

Definitions

Current Division Factor:	The fault current division factor, or split factor, represents the inverse of a ratio of the symmetrical fault current to that portion of the current that flows between the grounding grid and the surrounding earth.
Ground Potential Rise:	The maximum electrical potential that a substation grounding grid may attain relative to a distant grounding point assumed to be at the potential of remote earth.
Step Voltage:	The difference in surface potential experienced by a person bridging a distance of 1 m with the feet without contacting any grounded object.
TAO:	Transmission Asset Owner.
Touch Voltage:	The potential difference between the ground potential rise (GPR) and the surface potential at the point where a person is standing while at the same time having a hand in contact with a grounded

[1] Includes the earth grid and any TAO/TSO owned/operated parallel paths such as overhead line shield wires or cable sheaths directly bonded to the substation earth grid.

	structure.
Policy & Principles	<u>New Substations</u> For all new transmission substations the relevant system design short circuit level defined in the 110/220/400kV Station General Requirements Functional Specification [3] must be adopted as the maximum grid current for the substation earth-grid design. Where it has been clearly demonstrated by the customer (or TAO) that designing the earth grid using the aforementioned system design short circuit levels is impractical, EirGrid will carry-out a study to determine the maximum anticipated earth fault current at a particular new substation. The short circuit study must be carried out by simulating a single-line-to-ground fault at the substation busbar. This study must account for all planned network development projects and new generation and demand connections in the area, as detailed in the 'Calculation of Maximum Short-Circuit Current for Substation Earth Grid Design Methodology' [4], to ensure a robust earth grid design for the foreseeable future. The fault current level that will be provided to the customer (or TAO) is the single phase **Initial Symmetrical Short Circuit Current**. This current shall be used as the design earth fault current for the substation earth grid. The design and construction of the new substation earth grid must guarantee that the full earth fault current provided to the customer (or TAO) can be safely dissipated to remote earth through the earth grid, which may include the use of TAO/TSO owned/operated parallel paths such as overhead line shield wires or cable sheaths, whilst maintaining step and touch voltages within safe limits, as defined in IEEE80-2000. The use of local transformer neutrals as parallel paths is not permitted for the purposes of the substation earth grid design. <u>New Connections into Existing Substations</u> For the connection of new **Plant** into an existing substation, the suitability of the existing substation earth grid must be assessed by the TAO. A short-circuit study must be carried out by EirGrid to determine the maximum anticipated earth fault level at the substation. The short circuit study must be carried out by simulating a single-line-to-ground fault at the substation busbar. This study must account for all planned network development projects and new generation and demand connections in the area, as detailed in the 'Calculation of Maximum Short-Circuit Current for Substation Earth Grid Design Methodology' [4], to ensure a robust earth grid design for the foreseeable future. The single phase **Initial Symmetrical Short Circuit Current** is provided to the TAO to carry out the substation earth grid assessment. Where the TAO has demonstrated that the earth grid in the existing substation, (which may include the use of existing TAO/TSO owned/operated parallel paths such as shield wires or cable sheaths), is unable to safely dissipate the maximum fault current to remote earth while keeping the GPR within permissible limits and whilst maintaining step and touch voltages within safe limits, as defined in IEEE80-2000, the substation earth grid in question must be extended or reinforced to meet the short circuit level requirements. The use of local transformer neutrals as parallel paths is not permitted for the purposes of the substation earth grid design.

Justification	The design of transmission substation grounding systems must comply with the latest version of the Grid Code, the EirGrid 'Earthing and Lightning Protection Functional Specification' and be designed in line within the safe limits set out in the IEEE80-2000 'Guide for Safety in AC Substation Grounding', which is the widely adopted standard for grounding system design. The method used in this policy for the calculation of the maximum earth fault current for use in the design of the substation earth grid is based on the principles of IEEE80-2000. All future planned network development projects including new generation and demand connections are included in the fault level study. This is to ensure that a safe and secure earth grid is constructed that has the potential to accommodate any future increases in fault levels. The UK Engineering Recommendation G74, which is based on IEC 60909 (Calculation of Short-Circuit Currents in Three-Phase AC Power Systems), is used by EirGrid to calculate short circuit levels. IEEE80-2000 recommends simulating faults both inside and outside the substation (e.g. at various points on a transmission line) to determine the maximum grid current, as it is this current that will produce the largest GPR. A detailed fault level study was carried out and the results demonstrated no increase in fault current for faults outside the substation[2]. Hence, simulating a single-line-to-ground fault at the substation busbar has shown to be sufficient for earth grid design needs in this system. The 'Calculation of Maximum Short-Circuit Current for Substation Earth Grid Design Methodology' document details the methodology for the calculation of the maximum earth fault current for use in the design of the substation earth grid, including the case setup. As the earth grid design may include the use of TSO/TAO operated/owned parallel paths such as overhead line shield wires or cable sheaths, EirGrid will review all assumptions used regarding the use of parallel paths to ensure the correct current division (current split) has been calculated. The use of local transformer neutrals as parallel paths is not permitted for the purposes of the substation earth grid design. This approach is adopted to capture the most onerous scenario and to minimise uncertainty as the residual fault current that needs to be dissipated to remote earth through the earth grid is directly related to the status of these transformer neutrals.
Application	This policy applies to all new 110/220/400 kV substations or the connection of new **Plant** into existing substations in Ireland for which a Project Agreement has not yet been achieved.
Derogation	Derogation from this policy will be by exception, following EirGrid's Derogation Policy.

Revision History	**Version**	**Date**	**Summary of Changes/ Reasons**	**Authors**	**Approved By (Inc. Job Title)**
	v1.0	28/04/2015	New policy	John Leahy (PST)	Michael Walsh (Dir. Future Grids)

[2] Analysis of Maximum Short-Circuit Current for Substation Earth Grid Design, February 2015.

				Yvonne Coughlan (Man. PST)	John Fitzgerald (Dir. Grid Development) Andrew Cooke (Dir. Operations)
	V1.1	28/7/2015	Update to remove use of TAO/TSO owned/operated transformer neutrals.	John Leahy (PST) Yvonne Coughlan (Man. PST)	Aidan Skelly (Dir. Finance & Legal) John Fitzgerald (Dir. Grid Development & Interconnection) Robin McCormick (Dir. Operations, Planning & Innovation)
References	[1] IEEE80-2000 'Guide for Safety in AC Substation Grounding' [2] EirGrid 'Earthing and Lightning Protection Functional Specification' [3] Functional Specification 110/220/400kV Station General Requirements [4] Calculation of Maximum Short-Circuit Current for Substation Earth Grid Design, Methodology, Planning Support & Tariffs.				