ENGINEERING DESIGN STANDARD

EDS 08-1110

FAULT LEVELS

Network(s): EPN, LPN, SPN

Summary: This standard provides guidance on the calculation, application and availability of fault level data and the fault level constraints that apply to all projects.

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☐ Contractors
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New document to cover guidance on the calculation, application and availability of fault level data and the fault level constraints for all projects.
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1 Introduction

This standard provides guidance on the calculation, application and availability of network prospective short-circuit current (fault level) data, network fault level constraints applicable, and network fault level mitigation strategies.

Three-phase and earth fault levels are required for network planning and design work, especially for equipment specification, protection studies and system earthing design/assessment. The nature of fault level assessment undertaken depends on the intended use case and these can vary.

The fault level of a system provides an indication of the strength of the network. It shall be calculated accurately to make sure that all electrical components are rated to withstand the prospective fault current.

2 Scope

This document details the principles and methodologies applied in the calculation and assessment of prospective short-circuit current across all networks that form part of UK Power Networks (EPN, LPN, SPN). This standard applies to all voltages from LV up to 132kV.

3 Glossary and Abbreviations

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>DAR</td>
<td>Delayed Auto-reclose</td>
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<tr>
<td>DlgSILENT PowerFactory</td>
<td>UK Power Networks EHV network modelling software</td>
</tr>
<tr>
<td>DINIS</td>
<td>LPN Legacy HV network modelling software</td>
</tr>
<tr>
<td>DPC</td>
<td>Distribution Planning and Connection Code</td>
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<tr>
<td>DPlan</td>
<td>UK Power Networks LV and HV network modelling software</td>
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<tr>
<td>EHV</td>
<td>Extra High Voltage. Voltages above 11,000V; generally used to describe 20kV to 132kV distribution systems</td>
</tr>
<tr>
<td>ESQCR</td>
<td>Electricity Safety, Quality and Continuity Regulations 2002</td>
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<tr>
<td>FCL</td>
<td>Fault Current Limiter</td>
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<tr>
<td>CLR</td>
<td>Fault Current Limiting Reactor</td>
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<tr>
<td>GBSO</td>
<td>GB System Operator</td>
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<tr>
<td>GROND</td>
<td>Geographical Representation of Network Diagrams. EPN/SPN Legacy HV network modelling software</td>
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<tr>
<td>GSP</td>
<td>Grid Supply Point</td>
</tr>
<tr>
<td>HV</td>
<td>High Voltage. Voltages above 1000V; generally used to describe 6.6kV or 11kV distribution systems but may include higher voltages.</td>
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<tr>
<td>LTDS</td>
<td>Long Term Development Statement</td>
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<td>LV</td>
<td>Low Voltage. In relation to alternating current, a voltage exceeding 50 volts but not exceeding 1 000 volts</td>
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<td>NETS</td>
<td>National Electricity Transmission System</td>
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<tr>
<td>PLE</td>
<td>Planning Load Estimate</td>
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<tr>
<td>RMS</td>
<td>Root Mean Square</td>
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<tr>
<td>SLD</td>
<td>Single Line Diagram</td>
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<tr>
<td>Term</td>
<td>Definition</td>
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| UK Power Networks             | UK Power Networks (Operations) Ltd consists of three electricity distribution networks:
|                               | • Eastern Power Networks plc (EPN).
|                               | • London Power Network plc (LPN).
|                               | • South Eastern Power Networks plc (SPN).                                                                                                                                 |

### 4 Fault Level Assessment

The fault levels shall be assessed for all network alterations/reconfigurations and new customer connections or changes to existing customer connections. The only exception to this may be projects developed solely for like for like switchgear replacements.

To ensure continued compliance with ESQCR, all fault levels shall adhere to the following requirements when assessing the impact on any network equipment. If the fault level (as calculated in Section 5) at any part of the distribution network impacted is:

- ≥ 95% and ≤ 100% - fault level monitoring\(^1\) shall be installed at the associated primary or grid substation.
- > 100% - network fault level mitigation/reinforcement shall be required.

New connections shall not cause the prospective fault level to exceed 100% of the lowest component fault level rating within any given part of the network.

If the distribution network fault levels at the proposed point of connection exceeds 100% of the lowest component fault rating the point of connection shall not be made available until the fault level mitigation/reinforcement works have been completed.

Where calculated fault levels exceed 100% of equipment rating as described above, Network Control and Operations shall be informed of the potential fault level problem and the proposed mitigation strategies. Following confirmation and verification by Infrastructure/Distribution Planning and Outage Planning, fault level information pin symbol(s) shall be placed at the relevant site/plant on the network management system (PowerOn).

For long-term planning purposes, fault level forecasts shall be calculated as part of network Regional Development Plans for all Grid Supply Points (GSPs), Grid Substations, Primary Substations and Switching Stations. These forecasts shall be based on Planning Load Estimate (PLE) forecast peak demand data, planned network modifications and future contracted embedded generation and demand connections. The fault level forecasts shall also incorporate changes on the National Electricity Transmission System (NETS) where available.

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\(^1\) The rollout of fault level monitoring will be included as part of the UK Power Networks funded system monitoring programme hence this requirement will be captured in the revised version of EDS 08-5040 (Guidelines for the Provision of System Monitoring) currently under review.
5 Fault Level Calculation

5.1 Overview

UK Power Networks uses sophisticated computer software packages to analyse fault levels on the distribution network. The Superposition Method shall be used for all fault level calculations. Each analysis shall be based on an initial condition from an AC load flow to establish pre-fault voltage at each node within the network and shall be carried out in accordance with ENA EREC G74.

The assumption used in all calculations to ensure representation of the most onerous system conditions is:

- All connected circuits contribute to the fault when assessing the duties associated with feeder or transformer circuits, busbars, bus section or bus coupler circuit breakers and components of a mesh infrastructure.

Fault level calculations shall be calculated using a full representation of the relevant UK Power Networks DNO distribution network.

Distributed generation/storage shall be discretely represented and their electrical parameters shall be based on data provided by the owner of the embedded power station.

The network model used for fault level calculations shall use the full representation of the National Electricity Transmission System (NETS).

5.2 Short Circuit Current Terminology

Short-circuit current comprises an AC component with a relatively slow decay rate and a DC component with a faster decay rate. These combine to form a total waveform, which represents worst-case asymmetry (rare in practice). Refer to Figure 5-1.

![Figure 5-1 – AC and DC Components of Short-Circuit Current](image)

5.2.1 X/R Ratio

The DC component decays exponentially according to a time constant, which is a function of the X/R ratio (the ratio of reactance to resistance in the current paths feeding the fault). High X/R ratios mean that the DC component decays more slowly.
5.2.2 DC Component

Two equivalent system X/R ratios are used to calculate the DC component of the peak-make and peak-break short-circuit currents. An initial X/R ratio is used to calculate the peak-make current, and a break X/R ratio to calculate the peak-break current. The initial and break X/R ratios are calculated using the equivalent frequency method (IEC 60909-0:2016 Method C). This is because this is considered the most appropriate general-purpose method for calculating DC short-circuit currents.

The DC component of short-circuit current is calculated on the basis that full asymmetry occurs on the faulted phase for a single-phase-to-earth fault or on one of the phases for a three-phase to-earth fault.

5.2.3 Making Duties

The making duty on a bus section or bus coupler breaker is imposed when they are used to energise a section of busbar that is faulted or earthed for maintenance. Substation infrastructure (like busbars, supporting structures, flexible connections, conductors, current transformers, wall bushings and disconnectors) shall also be able to withstand the making duty.

The making duty on individual circuits is that imposed when they are used to energise a circuit that is faulted or earthed for maintenance. This encompasses the persistent fault condition associated with delayed auto-reclose (DAR) operation.

5.2.4 Breaking Duties

The role of bus section or coupler circuit breakers is to break the fault current associated with infeeds from all connected circuits if a fault occurs on an uncommitted section of busbar when busbar protection is used. Circuit breakers associated with a feeder, a transformer or a mesh corner are needed to break the fault current, on the basis that the circuit breaker which opens last clears the fault.

Circuit breakers associated with faulted circuits are needed to interrupt fault current in order to prevent damage to plant and maintain security and quality of supply.

5.2.5 Initial Peak Current

The first peak will be the largest, occurring at about 10ms after the fault occurrence. This is the short-circuit current that circuit breakers shall be able to close onto if they are used to energise a fault. This duty is known as the peak make - a name that is slightly misleading because this peak also occurs during spontaneous faults.

All equipment in the fault current path will be subjected to the peak-make duty during faults so should be rated to withstand this current. The peak-make duty is an instantaneous value.

5.2.6 RMS Break Current

This is the Root Mean Square (RMS) value of the AC component of the short-circuit current when the circuit breaker contacts separate. It does not include the effect of the DC component of the short-circuit current.
5.2.7 DC Break Current

This is the value of the DC component of the short-circuit current when the circuit-breaker contacts separate.

5.2.8 Peak Break

As both the AC and DC components are decaying, the first peak after contact separation will be the largest during the arcing period. This is the highest instantaneous short-circuit current that the circuit breaker has to extinguish. This duty will be considerably higher than the RMS break. Like the peak-make duty, it is an instantaneous value (therefore it is multiplied by the square root of 2) and includes the DC component too.

5.2.9 Choice of Break Time

The RMS break and peak break will depend on the break time. The slower the protection, the later the break time and the more the AC and DC components will have decayed.

The RMS break current shall be calculated using 60ms break time as a worst case to account for instantaneous-trip protection functionality. Where more detailed RMS break short-circuit current assessments are required, a more accurate protection operation time and circuit breaker trip time shall be used.

5.3 Setup for Standard Fault Level Calculations

The following standard set of variables shall be reported on as a minimum in all fault level study results for balanced faults:

- Initial short-circuit current (kA).
- Transient short-circuit current (kA).
- Peak short-circuit current (kA).
- Short-circuit breaking current, RMS (kA).
- Short-circuit impedance, real part (ohm).
- Short-circuit impedance, imaginary part (ohm).
- X/R ratio (peak).

For unbalanced faults, the following standard set of variables shall be reported on as a minimum in all fault level study results:

- Initial short-circuit current (kA).
- Transient short-circuit current (kA).
- Peak short-circuit current (kA).
- Short-circuit breaking current, RMS (kA).
- Zero-sequence impedance, real part (ohm).
- Zero-sequence impedance, imaginary part (ohm).
- Positive-sequence impedance, real part (ohm).
- Positive-sequence impedance, imaginary part (ohm).
- Negative-sequence impedance, real part (ohm).
- Negative-sequence impedance, imaginary part (ohm).
5.3.1 DlgSILENT PowerFactory

For standard fault level calculations using the DlgSILENT PowerFactory software package, the setup shown in Appendix A shall be used.

Figure A-3 and Figure A-4 in Appendix A show the standard set of variables that should be provided as a minimum for all fault level study results for balanced and unbalanced faults respectively.

5.4 Data Requirements

Technical data that allows the calculation of fault infeed values at customer installations shall be provided by the owners of the installation in accordance with the Distribution Planning and Connection code (DPC1.6).

At the initial application stage, customer embedded generation assessments may be undertaken using discrete models based on data provided on the ENA application form. However, once detailed planning data is made available as per DPC1.6, individual models based on complete SLDs and customer network parameters shall be used.

For long term planning purposes, the full representation of the National Electricity Transmission System (NETS) used shall be that provided by the GB System Operator (GBSO) as part of the annual Week 42 data.

For operational planning purposes, the week ahead NETS model as provided by the GBSO shall be used.

5.4.1 Synchronous Generators

All directly connected embedded synchronous generating units should be individually modelled, together with the associated transformers.

The units shall be represented in terms of their sub-transient and transient reactances, as well as the stator resistances and negative-phase sequence reactances. Saturated values should be used to ensure calculation of the most onerous scenario.

Fault level studies for planning purposes shall be carried out under maximum plant conditions to simulate the most onerous possible scenario.

5.4.2 Converter Connected Generators

All directly connected embedded converter connected generating units should be individually modelled together with the associated transformers. A converter connected generator contributes between 1.2 to 2.5 times of its rated output.

The units shall be represented in terms of their sub-transient fault current contribution where available. In case of the converters having fault ride through capability the transient fault current contribution should also be entered for calculation.

Where detailed information is not available, a sub-transient fault current contribution of 1.5 times of rated output shall be assumed.
5.4.3 Substation Demand Infeed Data

Detailed infeed data for dynamic loads at Secondary, Primary, Grid and GSP sites should be used wherever available. The fault contribution infeed shall be represented by a separate element on the appropriate substation in the model used for calculation. In DlgsILENT PowerFactory, the network model Technical Administrator shall update this element when creating new base models.

Where detailed information is not available, 1.1 MVA of fault infeed per MVA of substation demand with an X/R ratio of 2.76 shall be assumed. All fault level calculations should be carried out using the peak substation demands. This approach reflects the requirements of ENA EREC G74. The import demand of battery storage installations connected at HV up to 132kV shall be excluded from the peak substation demands for calculation purposes, as they are converter connected.

Where more detailed fault level studies are needed at LV, the associated HV and LV system shall be modelled in detail, down to individual LV busbars. Dynamic load infeeds should be represented at LV if present. General LV three-phase fault level data can be estimated as per ENA EREC P25 when required.

6 Fault Level Mitigation Strategies

Typical methods employed by UK Power Networks to mitigate/resolve fault level constraints include.

- Fault current limiter (FCL).
- Fault current limiting reactor (CLR).
- N-1 intertrip.
- Auto-switching schemes (includes sequential switching to address peak make current issues).
- Generator inhibit schemes.
- Asset Replacement.

The choice of the mitigation strategy shall be considered on a case-by-case basis informed by consultation with all relevant key stakeholders (Asset Management, Network Operations, Connections and Capital Programme).
7 Long Term Development Statement

7.1 Fault Level Values

7.1.1 EHV Fault Levels

Fault level data for the 132kV, 33kV and 11kV primary busbars is available from Tables 4A and 4B in the Long Term Development Statement (LTDS) (see Section 7.2) for normal running arrangements.

More detailed fault level data shall be calculated using the EHV network modelling tool (D1gSILENT PowerFactory).

7.1.2 HV Fault Levels

Fault level data for the 2kV, 3kV, 6.6kV and 11kV secondary networks is available from the relevant HV network modelling tool (DPlan, GROND or DINIS).

7.2 Long Term Development Statement Access

To request a copy of the Long Term Development Statement (LTDS) please register with UK Power Networks by providing the following information:

- Company name, full address (including postcode) and Company registration number.
- Contact name.
- Telephone number.
- Email address.
- Website address.

All requests should be sent to: mbx-networksstrateg@ukpowernetworks.co.uk.

To discuss a specific enquiry relating to a new connection to the distribution network or an enhancement to an existing connection please contact connections.gateway@ukpowernetworks.co.uk or visit www.ukpowernetworks.co.uk.

A copy of the LTDS within each region is also available internally within Alfresco under the following path:

Intranet > Policies Procedures & Forms > Engineering > Network and Site Specific > (EPN/LPN/SPN) > Long Term Development Statement
8 References

8.1 UK Power Networks Standards

- EDS 08-3000 HV Network Design
- EDS 08-3100 HV Customer Demand and Generation Supplies
- EDS 08-4000 EHV Network Design
- EDS 08-4100 EHV Customer Demand and Generation Supplies

8.2 National and International Standards

- ENA EREC G74 Procedure to Meet the Requirements of IEC 909 for the Calculation of Short-circuit Currents in Three-phase AC Power Systems
- ENA EREC P25 The short-circuit characteristics of single-phase and three-phase low voltage distribution networks

9 Dependent Documents

The documents below are dependent on the content of this document and may be affected by any changes.

- EDS 08-3000 HV Network Design
- EDS 08-3100 HV Customer Demand and Generation Supplies
- EDS 08-4000 EHV Network Design
- EDS 08-4100 EHV Customer Demand and Generation Supplies
Appendix A – DlgSILENT PowerFactory

A.1 Setup for Standard Fault Level Calculations

Figure A-1 – Short-Circuit Calculation Basic Options
Figure A-2 – Short-Circuit Calculation Advanced Options
A.2 Standard Variables for Fault Level Study Results

Figure A-3 – Result Variables for Balanced Faults

Figure A-4 – Result Variables for Unbalanced Faults