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Resilience to Flooding of Grid and Primary Substations

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Amendments since publication

Issue	Date	Amendment

Contents

References

1. Environment Agency--What is the updated Flood Map for Surface Water?
This document includes references to other documents on Surface water Flooding.

2. The latest updates to the Environment Agency's 'Flood Map', 'Historic Flood Map' and 'Recorded Flood Outlines' for England
Now available through the EA's DataShare Website.
The Flood Map has also been published on gov.uk, where it is referred to as the 'Flood Map for Planning (Rivers and Sea)'. Wales and Scotland flood maps can be found respectively at Natural Resources Wales and Scottish Environment Protection Agency (SEPA).

3. The Flood Estimation Handbook
A set of five printed volumes (Centre for Ecology & Hydrology, 1999, ISBN: 9781906698003), priced from £260. Individual volumes from the set are not available. Wallingford HydroSolutions sell and support the *Flood Estimation Handbook* and its related software.

4. Comparison of Environment Agency surface water flood maps
Appendix A of the Environment Agency (EA) document Guidance on surface water flood mapping for Lead Local Flood Authorities, Report version 2.0, 21 December 2012.

5. Surface water flooding – Suggested methodology for assessment
Appendix B of the Environment Agency document Guidance on surface water flood mapping for Lead Local Flood Authorities, Report version 2.0, 21 December 2012.

6. Fluvial and coastal flooding – Suggested methodology for flood modelling
Environment Agency document National Generalised Modelling for Flood Zones - Fluvial & Tidal Modelling Methods - Methodology, Strengths and Limitations, March 2006.

7. National Flooding Resilience Review – How the country can be better protected from future flooding and extreme weather events
Review of how we assess flood risk, reduce the likelihood of flooding, and make the country as resilient as possible to flooding, (DEFRA, Cabinet Office, EA, MetOffice, September 2016). Full document located here.

Introduction

The serious incidents of flooding in the South Midlands and South Yorkshire during the summer of 2007, and the incident at Carlisle in 2005 highlighted the potential vulnerability of electricity substations to major flood incidents. More general concerns over global warming and rising sea levels also bring into question whether historic levels of protection from flooding will be adequate in the future.

The Electricity Safety, Quality & Continuity Regulations (ESQCR) 3 (1) (b) state that "Generators, distributors and meter operators shall ensure that their equipment is so constructed, installed, protected (both electrically and mechanically), used and maintained as to prevent danger, interference with or interruption of supply, so far as is reasonably practicable." However, in the absence of any specific guidance on what is an acceptable level of flood risk or any regulatory impact assessment, the extent of the duty has been unclear. Since the introduction of the ESQCR, far more information relating to flooding has become available to both assess flood risk to substations and to understand the mitigation options and costs. This has facilitated the development of this ETR, which sets out a common approach to the assessment of flood risk and the development of target mitigation levels that are subject to cost benefit assessment.

Following the incidents in 2007, the Energy Minister requested a comprehensive assessment of the resilience to flooding of primary and higher voltage substations and the steps that may be taken to mitigate current and future risks. The Energy Networks Association (ENA) Substation Resilience to Flooding Task Group, reporting to the Energy Emergencies Executive Committee, (E3C) was asked to lead this work within agreed Terms of Reference.

At the same time the government established the Pitt Review1 to consider all aspects of flood prevention and the ENA Task Group worked with the Pitt Review Team to ensure a co-ordinated approach.

The Task Group Report was delivered to E3C and The Energy Minister at the end of March 2008. The Report was accepted and a further phase of work requested to oversee the implementation of the recommendations in the Phase 1 Report and the production of Version 1 of Engineering Technical Report (ETR) 138 in October 2009.

The guidance is focussed on GB but the principles also apply in Northern Ireland as appropriate.

Following the publication of Version 1 of ETR 138 additional information became available on surface water (pluvial) flooding as well as flooding due to reservoir dam failures and canal bank bursts. The second version of ETR 138 issued in April 2016 includes recommendations on the management of these additional flood risks together with a number of general updates.

During December 2015, exceptional flooding occurred in areas of northern England, Wales and Scotland due to storms Desmond, Eva and Frank just prior to the publication of Issue 2 of this document. This flooding overtopped a number of public flood defences and flooding occurred at some major substations causing substantial loss of supplies to customers.

1Pitt Review-- LEARNING LESSONS FROM THE 2007 FLOODS - A report by Sir Michael Pitt into the serious flooding that affected parts of England in 2007

Following the 2015 flooding, the Environment Secretary announced a National Flood Resilience Review to better protect the country from future flooding and increasingly extreme weather events. The review considers how flood risk is calculated taking into account recent events. This involved Government updating 'worst case scenario' planning, considering the future impacts of climate change and carrying out a risk assessment of critical infrastructure including electricity substations.

The review recognises the substantial programme of flooding resilience work being undertaken by electricity transmission and distribution Network Operator's in accordance with ETR 138.

However, the review makes one particular recommendation that has led to a revision of this ETR. This recommendation calls for the development of longer term plans for permanently improving the resilience of service provision to sites supplying significant local communities (SLCs) from the flooding defined by the Environment Agency's Extreme Flood Outlines.

This could be delivered by increasing interconnectivity to enable service provision to be re-routed in the event of asset loss, or by the installation of permanent defences at significant local infrastructure asset sites, or (in cases where permanent defences are not cost-effective) through other measures where this is feasible.

SLCs are defined as those communities comprising at least 10,000 customers/connections and the Environment Agency's Extreme Flood Outline is defined as a 1/1,000 flood risk. This document considers a connection as a single customer in the same way that Customer Interruptions and Customer Minutes Lost are treated.

The guidance in Issue 3 of this document has been updated to consider the above issues.

In addition, network operators have identified that extreme rainfall can result in water scour that is severe enough to threaten overhead line structures and buildings and it is considered that guidance on this issue should be provided in a separate document.

1 Scope

This ETR addresses the risk management of floods at grid and primary substations in England, Scotland and Wales due to coastal, river and surface water flooding. Guidance is also provided on understanding the potential impact of water main bursts, reservoir dam failures and canal bank bursts. The impact of groundwater penetrating flood defences is also considered.

Where practicable a similar approach should be taken in Northern Ireland subject to local legislation.

2 Purpose

The aim of this ETR is to provide guidance on how to improve the resilience of electricity substations to flooding to a state that is acceptable to customers, Ofgem and Government using a risk-based methodology and taking account of a cost/benefit assessment for each site.

The following key areas are covered:

- The impact of flooding on the GB Electricity Supply System and risks for society
- Available flood risk information and its use.
- National flood defences and planning requirements.
- Systematic approach to Flood Risk Assessment and the identification of appropriate protection including;
  i. Conducting Flood Risk Assessments for each Substation;
  ii. Identification of the flooding impact for each particular site and individual assets;
  iii. Establishing if a site will be protected by a National flood protection scheme;
  iv. Where necessary, identifying the most appropriate flood protection system for each site.
- Levels of acceptable flood risk and implications for investment including a Cost/Benefit assessment that takes into account Societal Risk as indicated in Section 7.3.
- Work Programmes for implementation of Substation Flooding Resilience which will be dependent on the availability of necessary funding.

Within the general principles set out in Section 8, Network Operators may determine their own method for assessing the detailed costs and benefits. However, for sites with more than 10,000 unrecoverable connections, resilience against a 1/1000 flood event should be the target level of resilience. In exceptional circumstances, Network Operator's will provide such level of resilience as is reasonably practicable in the circumstances (Section 8 provides further details.)

3 Impact of flooding on the GB Electricity Supply System and risks for society

Background information on the GB Electricity Supply System is provided in the Annex document to ETR 138.

Flooding can affect underground cables by revealing weaknesses and may cause operational issues on overhead lines. However, substations can be particularly vulnerable if water reaches certain critical depths and, as explained below, the impact of substation flooding can be particularly severe.

The relative importance of different types of substation is indicated in Table 1 below and illustrated in the photographs in the Annex document to ETR 138, which show some of the equipment more vulnerable to flooding. This ETR considers primary and higher voltage substations. Distribution substations generally serve a very small geographic area and, if flooded, the customers they supply are also normally flooded and unable to take a supply of electricity. They generally do not supply customers outside the flood area and can be restored much more quickly when the flood waters subside. However, distribution substations may need protection in certain circumstances if they supply other key electrical infrastructure or other critical infrastructure as described in Section 8 of this document.

Substation Type	Typical Voltage Transformation Levels	Approximate number	Typical Size	Typical Number of Customers Supplied
Grid	400kV to 132kV (Transmission system)	377	250m by 250m	200,000 - 500,000
	132kV to 33kV (Distribution system)	1,000	75m by 75m	50,000 - 125,000
Primary	33kV to HV (Distribution system)	4,800	25m by 25m	5,000 - 30,000
Distribution	11kV to 400/230V (Distribution system)	230,000	4m by 5m	1 - 500

Table 1 - Types of electricity substation

Experience of flooding incidents underlines the particularly severe impact on society of a combination of flooding and loss of electricity supplies to a large community, especially if this also affects other critical infrastructure such as water, gas, sewage or telecommunications.

Critical infrastructure comprises those sectors which supply essential services to the citizen on which normal daily life in the country depends. For the purposes of this ETR, the identification of those organisations providing these essential services is covered in Section 7 and uses the protected site list of the Electricity Supply Emergency Code (ESEC) as a guide. This list is subject to review by BEIS and Network Operator's should ensure they use the latest version.

To understand the consequence and impact of flooding, it is important to consider the duration of any failure and the social distress at a time when it's likely that other critical infrastructure will be stretched. This issue is summarised in Appendix 1.

4 Flood Risk Information

4.1 Overview

The following organisations outlined in table 2 produce flood risk information, Appendix 2 provides additional information on the assessment of flood risk.

Location	Organisation	Flood Warnings	Flood Mapping	Flood Depth Mapping
England	Environment Agency	Yes (Including telephone warnings)	Yes	Yes via EA Area Offices but limited coverage.
Wales	Natural Resources Wales	Yes (Including telephone warnings)	Yes	Yes via EA Area Offices but limited coverage
Scotland*	Scottish Environment Protection Agency	Yes (Including telephone warning)	Yes	Yes
Northern Ireland	Rivers Agency	Via MetOffice	Yes	Yes

*National flood mapping only. Scottish Local Authorities under existing duties (Flood Prevention Authority) may have local flood mapping to support these duties.

Table 2 - Authorities responsible for flood risk information (Fluvial, Pluvial, and Coastal)

4.2 Flood Mapping

4.2.1 Fluvial and Coastal Flooding

At present, the EA has coverage of flood risk mapping across England, showing areas at risk with probability levels of 1/1,000 and 1/100 chance of occurrence in any year for fluvial flooding and 1/1,000 and 1/200 chance of occurrence in any year for coastal flooding. These probabilities are modelled without any EA flood defences in place as defences can be breached or overtopped.

This flood mapping can be supplied electronically and, using appropriate software that is commercially available, Network Operators are able to populate the flood map with the locations of all their substations and produce a list of substations in the areas at risk of flooding.

More detailed modelling and mapping data (including depths in some cases) is held by the EA and can be made available for those critical sites identified at risk of flooding. Data is generally held as depth Above Ordnance Datum (AOD) which requires conversion to obtain site depth. Coverage of depth and more detailed data is generally limited to areas of highest risk such as cities/towns and therefore this information is only available for a limited number of sites.

In Scotland the “Indicative River and Coastal Flood Map” (Scotland) (IRCFMS) provides similar flood plain data. In some local areas, primarily the Clyde through Glasgow, higher resolution data sets may be available. For all other areas, whilst the underlying models capture water depth at each model cross sections, the depths are related to the Digital Terrain Model (DTM) and not to Ordnance Datum (OD).

SEPA may be able to provide flood depth data from the IRCFMS for appropriate Network Operators. However, this data must be used carefully given the indicative / strategic nature of the maps and the underlying data sets used in developing the product. Whilst SEPA has been funded to carry out a national flood mapping program (IRCFMS), Local Authorities may also carry out mapping exercises, particularly in support of their functions as the Flood Prevention Authority.

The EA, Natural Resources Wales and SEPA hold historical flood information and, in certain situations, maps which can provide additional information for the assessment of flood risks at particular sites. Section 8 details key flood risk information required by Network Operators. The provision of robust flood depth data is essential for the proper assessment of flood risk to substations and the identification of appropriate protection.

Where information such as flood depth is not available from the EA, Natural Resources Wales or SEPA, Network Operators will need to carry out “Flood Risk Assessments” (FRAs) and calculate predicted flood levels in accordance with The Flood Estimation Handbook (Reference 3). Network Operators may also wish to carry out FRAs at sites where data from the EA, Natural Resources Wales and SEPA is available in order to confirm detailed site impacts. These FRAs may be made available to the EA and SEPA who are able to review the procedures employed and the results obtained.

4.2.2 Pluvial Flooding

Following the recommendations in the Pitt Review, the EA, Natural Resources Wales and SEPA have carried out a considerable amount of work to understand the potential impact of pluvial flooding.

The EA has produced a new national scale surface water flood mapping for England and Wales which was published in December 2013.

The updated Flood Map for Surface Water improves on the Flood Map for Surface Water (2010) and the Areas Susceptible to Surface Water Flooding Maps (2009) in the following ways:

- Incorporates improvements in modelling techniques, understanding and data;
- Combines appropriate local mapping from Lead Local Flood Authorities (LLFAs) with national mapping to provide an improved and consistent picture of surface water flood risk; and
- Provides velocity and depth information for a range of flood probabilities.

Although the updated national scale surface water flood mapping is an improvement, there remain a number of assumptions in the model:

- The EA has digital terrain information for over 90% of urban areas in England and Wales at 2m resolution or finer, yet there are still some areas with coarser resolution data (5m) where the flood maps will be less detailed;
- The EA has better technology, data, and modelling techniques, yet the model cannot represent every detail of the urban landscape and very local mechanisms of flooding;

- Drainage capacity is the biggest factor of uncertainty in the modelling; the EA has to make assumptions where no drainage data is available and therefore the outputs of the model may be less accurate.

Please refer to Reference 5 for further information on modelling parameters.

In addition, it is recognised that surface water flood maps can be obtained through flood risk consultants who specialise in this area of work. In order that Network Operator's apply a consistent approach to flood risk modelling it is recommended that the modelling techniques and parameters used by the EA and SEPA are adopted and this is summarised in Reference 5.

As a result of the improvements made in pluvial flood mapping it is now recommended that Network Operators take account of pluvial flood risk when assessing substation flooding resilience.

4.2.3 Impact of Climate Change

Guidance on the impact of climate change on flood risk is provided within the following documents:

- England— National Planning Policy Framework (NPPF) and in the associated Technical Guidance to the National Planning Policy Framework;
- Wales— Technical Advice Note (TAN) 15 provides technical guidance which supplements the policy set out in Planning Policy Wales in relation to development and flooding;
- Scotland— Scottish Planning Policy (SPP) 7 and National Planning Framework for Scotland 2 (NPF2) and the associated Technical Guidance to NPF2.

Network Operators should consider the latest versions of this guidance at the appropriate part of the "Systematic Approach to Flood Risk Assessment and Protection" detailed in Section 8.

4.2.4 Other Flood Risks

It is recommended that Network Operators should also consider the following additional flood risks:-

<u>Reservoir Failure</u>

Rapid and very damaging inundation of large areas downstream from reservoir dams can occur if the reservoir fails unexpectedly. A feature of this type of flooding is the speed and height of the flood wave which can be particularly destructive. Information on the predicted flood impact of dam breaches has now been made available by the EA and SEPA.

Because of the difficulty of protecting against this type of incident it is expected that any action will normally focus on effective recovery plans to ensure that services can be restored as quickly as possible.

In Scotland, under the Flood Risk Management Act 2009, SEPA has new duties including the development of dam breach inundation maps. The programme is on-going and a dialogue will be maintained with SEPA to ensure that the most up-to-date information is available.

Canal Bank Bursts

Most canals are the responsibility of the Canal and River Trust. The Trust have undertaken ISIS 2D modelling of their principal and non-principal embankments and culverts, to determine the breach risk they pose (zone of inundation, depth & velocity of water, extent of property damage, average annualised damages etc). Discussions will continue with the Trust to gain access to the findings.

Although the Canal & River Trust is the largest navigation authority in England & Wales, they do not have responsibility for all canals in England and Wales (others are owned and managed by different navigation authorities, a list of which can be obtained at AINA website, although the Trust advises it is not aware of any other authority having carried out any form of breach risk analysis for their assets). The Canal & River Trust no longer has responsibility for canals in Scotland. Scottish Canals (www.scottishcanals.co.uk) have responsibility although the Canal and River Trust undertook the breach risk modelling work for all of the waterways in England, Wales and Scotland that were under the responsibility of their predecessor body, British Waterways, before July 2012, when the separation between Scotland and England/Wales took place.

The Trust plans to make information on breach risk available via the National Resilience Extranet.

Network operators will review the significance of this data when it becomes available. However, as with dam bursts, because of the difficulty of protecting against this type of incident it is expected that any action will normally focus on effective recovery plans to ensure that services can be restored as quickly as possible.

Water pipe bursts affecting underground substations

This risk predominantly applies to large cities. In London, action has been taken to identify substations at risk from large water mains in the vicinity and protective measures are being put in place. Network Operators indicate that there are very few sites outside London where this risk exists but Network Operators have nevertheless undertaken to share experiences and best practice.

5 Flood Defences and Planning Requirements

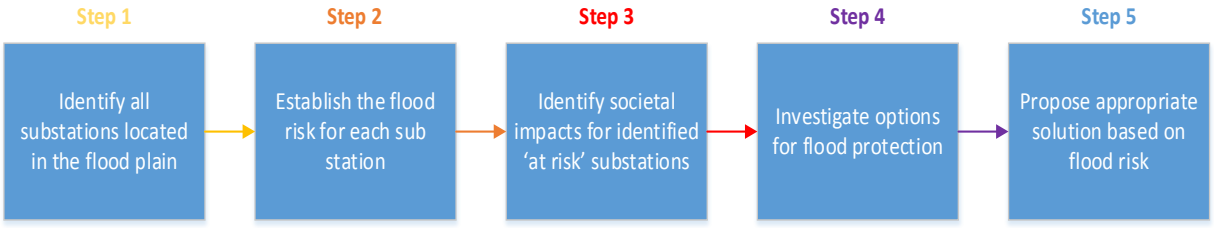
The principal authorities empowered to deal with flood defence matters on main rivers across the UK are the appropriate regional agencies, EA, SEPA, NRW and the Rivers Agency.

Supporting information on planning requirements is provided in Appendix 3.

6 Systematic Approach to Flood Risk Assessment and Protection

6.1 Overview

This ETR identifies a number of steps in a systematic approach to ensure the resilience of grid and primary substations against flood risk. This approach can be summarised as follows:



Step 1:

Identify all substations in the flood plain for fluvial, pluvial and coastal flooding using best available current data as indicated in section 6. In order that Network Operator's apply a consistent approach to flood risk modelling it is recommended that the modelling used by the relevant authority is adopted. For EA this is summarised in Reference 5. For fluvial and coastal flooding a consistent data collection approach is required. The following key points should be noted:

a) The best information available is required to ensure that the risk at individual sites can be properly assessed and the most appropriate flood protection measures put in place at the optimum level of investment at a national level.

b) This data collection should include:-

- Whether the site is in an area that could be affected by flooding, i.e. is the site on the flood plain for probability levels of 1/100 (1/200 in Scotland) or 1/1,000 for fluvial flooding and 1/200 or 1/1,000 probability for coastal flooding.
- Whether the site benefits from a flood defence scheme provided by:-
- The EA in England, Natural Resources Wales and the Rivers Agency in Northern Ireland;
- Local Authorities in Scotland; or
- Site owner or any other party.
- Condition of the defences protecting the site. (Grades 1-5 in the EA scheme.) In order to assess this information in more detail, including the degree of protection and predicted life of the defences, Network Operators will need to discuss the position with the appropriate authority.
- Flood risk including potential maximum level of flood water for the probability levels above. An indication of data accuracy and Flood Zone type in accordance with National Planning Policy Framework, Technical Advice Note 15 and Scottish Planning Policy 7, subject to data availability.
- Accuracy and age of terrain mapping.
- Confidence rating for the data, where available.
- Whether the site is in an EA/SEPA/NRW or Rivers Agency flood warning area.
- Lead time for flood warning.
- Minimum notice required by the Network Owner to put in place any temporary flood protection measures.

- Historical Flooding Information.

c) Separate data specifications will be used for England, Wales and Scotland.

d) Network Operator will need to consider with any storm/tidal surge impacts that could affect coastal regions to establish whether substations will be appropriately protected by area schemes and if not what action Network Operators can reasonably take to protect these sites.

For pluvial flooding, Network Operators should use the latest surface water flood map information published by EA, Natural Resources Wales and SEPA to assess those sites that may be at risk. In order to assess the flood risk in detail, Network Operators may need to engage the services of specialist flood risk consultants. Network Operators should ensure that the basis for calculating flood depths used by their consultants is consistent with the methodology used by the appropriate flood authority. As indicated in section 6 above, in order that Network Operator's apply a consistent approach to flood risk modelling, it is recommended that the modelling used by the EA, Natural Resources Wales and SEPA is adopted and this is summarised in Reference 5.

The predicted level of flooding will also need to take into account the uncertainties surrounding climate change. Based on current advice provided by the EA/NRW/SEPA, it is recommended that for the flood risk assessments under this ETR, the information on flood depth is increased by the following amounts:

- Uncertainty and Freeboard
    - Increase by 300mm to allow for uncertainties in data and modelling.
- Fluvial and Pluvial Flooding
    - Network Operator's should use the latest information available from the responsible agencies. New information was made available by EA in February 2016 and it is expected that the other agencies will update their guidance. The period chosen for climate impacts should match the planned lifetime of the assets being protected. Until guidance is updated, Network Operator's should use an assumption of an additional 20% on the predicted flood depth, to allow for climate change impacts during the planned lifetime of the assets.
- Sea Level Rise
    - Network Operator's should use the latest information available from the responsible agencies. New information was made available by EA in February 2016 and it is expected that the other agencies will update their guidance. The period chosen for climate impacts should match the planned lifetime of the assets being protected.

Clearly, the addition of these contingencies is likely to increase the cost of any protection works and this will be taken into account in the detailed assessment of the costs and benefits for each site referred to below.

Step 2:

Establish the flood risk for each substation to identify predicted flood depth and other key factors to establish which substations are "at risk" i.e. where the predicted depth of flooding is

likely to cause damage to key parts of the substation resulting in the loss of supplies to customers.

In order to assess the flood risk in detail, Network Operators may need to engage the services of specialist flood risk consultants. Network Operators should ensure that the basis for calculating flood depths used by their consultants is consistent with the methodology used by the appropriate flood authority.

Step 3:

Having assessed the flood risk as described in Step 1 and 2, it is necessary to consider the flooding impact on each primary and higher-voltage substation in the flood plain. This is achieved by comparing the predicted flood level with the level of critical equipment that, if flooded, will cause supplies to be interrupted. Then, for each substation that is "at risk" of flooding, identify the societal impact including connected customer numbers and any interdependencies with other critical infrastructure.

Critical equipment may be high-voltage apparatus but is equally likely to be auxiliary equipment such as outdoor control kiosks or indoor protection, control or battery equipment. The Annex document to ETR138 includes a more extensive list of typical equipment which may be critical to the continued safe operation of a substation.

If critical equipment is not threatened by the predicted level of flooding then no specific flood defences are required, although these sites need to be identified in the Network Owner's Emergency and/or Flood Response Plan(s) to ensure staff understand the flood risk and the means by which safe access may be achieved during a flooding event.

If critical equipment is threatened, then the position and type of equipment and the predicted flood depth will allow the most appropriate flood protection system to be determined.

The potential impact on society resulting from the loss of any substation should be assessed taking into account relevant factors including the following:

- Always applicable
    - The number of customers who would lose their supplies if the substation were to be shut down
    - Whether it is possible to quickly restore supplies to customers in the event of substation loss due to existing network interconnection/back-feeds.
    - Ongoing network risk whilst the flooded substation is restored to full operation e.g. robustness of interconnection/back-feeds, repair time, availability of replacement plant, site access issues etc.
- Applicable when appropriate
    - The effect of supply loss on Critical Infrastructure sites (For the purposes of this ETR the protected customers list in the Electricity Supply Emergency Code should be used as a guide to identify critical infrastructure services. The infrastructure sites which are most essential to society are those where loss of service to the community is likely to lead to mass evacuation, and includes major water, sewage and land drainage sites).