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Resilience to Flooding of Grid and Primary Substations

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Amendments since publication

Issue	Date	Amendment

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Annex 1 GB Electricity Distribution System

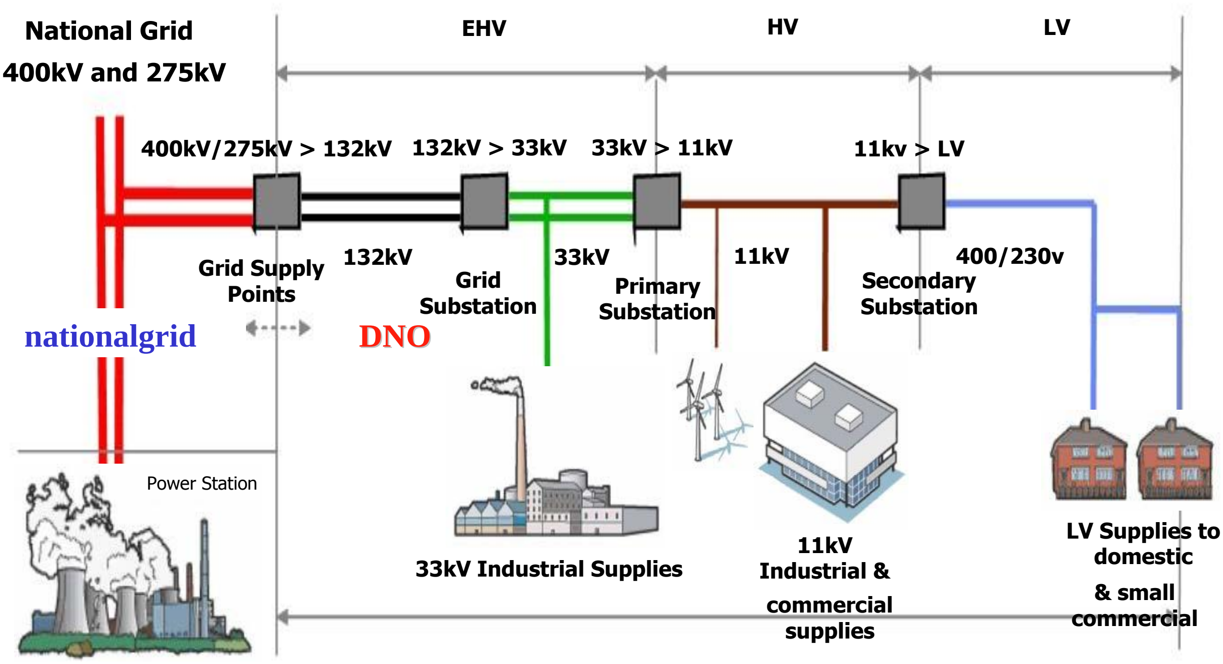
A1.1 Overview of the GB Electricity Distribution System and Impact of Flooding

Network businesses in GB operate under licences issued by Ofgem and are subject to a Regulatory framework set by Ofgem. They also are subject to statutory requirements including The Electricity Act and Electricity Safety Quality and Continuity Regulations (ESQCR) which are overseen by BEIS and the Health and Safety Executive (HSE).

Spending plans for the industry are agreed by Ofgem with individual Network Owners every eight years and these reviews govern all expenditure which includes flood mitigation and emergency planning. This provides common oversight and accountability to Ofgem and BEIS.

In GB, electrical power is transported from generating plants to customers over networks managed by Transmission and Distribution Network Owners. The Transmission System operates at typically 400,000 volts (400kV) or 275kV (and 132kV in Scotland) and the Distribution system operates at voltages from 132kV to the normal household voltage of 230V. This is shown below.

Electricity Supply Chain



In England and Wales, National Grid own and operate the Transmission System whereas in Scotland the Transmission Networks are owned by Scottish Power and SSE but operated by National Grid and the interface between transmission and distribution systems takes place within grid substations at 33kV.

These systems comprise a mixture of overhead lines and underground cables that generally are not susceptible to flooding but there is a potential for statutory safety clearances to be affected in flood conditions. In addition there are points on the system, called substations, where voltage transformation takes place and switching and control equipment are located. The type of equipment operating at these substations can be vulnerable to flooding if water reaches certain critical depths. The loss of supply incidents in 2007 in Yorkshire and Gloucester all occurred as a result of substation flooding when the exceptionally high water levels reached critical depths at some substations.

The relative importance of different types of substation is indicated in Table 1 below and the photographs in Appendix 4 of the main report illustrate the substations and some of the equipment more vulnerable to flooding. This report considers Primary and higher voltage substations. Distribution substations 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 are easier to protect and much quicker to restore when flooding subsides.

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

A1.2 Emergency Planning

Emergency planning issues of shared interest to the government, industry and the regulator are reviewed and managed through the framework of the Energy Emergencies Executive (E3). The Executive is made up of a senior representative from each of BEIS, industry and Ofgem, and is supported by a committee (E3C) chaired by a Director of National Grid and comprising representatives from electricity companies, trade bodies, BEIS and Ofgem. The committee meets every two months and has a number of active task groups working on various issues. This ENA led review of the resilience of substations to flooding is an example of the work undertaken within the E3 framework.

Network Owners have well developed emergency plans to ensure an effective response to a range of events that can affect both Transmission and Distribution networks. Overhead line systems are susceptible to severe weather conditions, such as wind storms and lightning, and consequently Network Owners are required to implement their emergency response procedures on a regular basis which ensures they are tested and practiced. These plans also cover flooding incidents. Customer communication for problems affecting customers' supplies is the responsibility of Distribution Network Owners and they have sophisticated telephony systems that are capable of answering very large numbers of simultaneous customer calls.

Through the ENA, Network Owners meet regularly to review emergency planning and response arrangements including such issues as Black Start and rota disconnection.

Network Owners are all members of a mutual aid consortium called NEWSAC. In an emergency affecting one or more member companies, the NEWSAC group representatives will assess the availability of resources from those companies least affected and agree the allocation of these resources based on the level of damage. The NEWSAC agreement was successfully implemented during the 2007 floods when Northern Power Grid received assistance from Scottish Power and Western Power Distribution. It was also implemented very successfully in the South of England floods in 2014 and North of England floods in 2015 when temporary flood barriers and generators were also dispatched.

Network Owners also work closely with other Utilities, the Emergency Services and Local Authorities under the terms of the Civil Contingencies Act. This includes working with Local Resilience Forums on emergency planning, taking part in exercises and participating in Gold, Silver or Bronze Commands. The Electricity Act and the ESQCR already include powers for the Secretary of State in relation to continuity of supply and' if necessary, to give directions for preserving security of electricity supply. The Minister twice exercised these powers in 2002 in the setting up of independent reviews of "Resilience of the Electricity Supply Industry". These arrangements have proved effective and it is recommended that any improvements in the resilience arena are implemented through the existing BEIS/Ofgem oversight.

A1.3 Flooding Events and Flooding Resilience

Prior to 2007, widespread flooding events occurred in 2000 and 2005. In 2000, serious floods affected large parts of the country including the South East of England, Shropshire and Yorkshire, when electricity supplies were affected. In 2005, severe flooding affected Carlisle including Carlisle Grid Substation. This resulted in power outages across most of Carlisle for approximately 36 hours. The joint Industry/BEIS survey following the Carlisle incident in 2005 sought to identify primary and higher voltage substations at risk against the then published EA Flood Maps for England and Wales for 1 in 100/200 and 1/1,000 return events. A total of 1,040 substations were identified but flood depth prediction was not generally available and therefore the likely impact of any flooding was not assessed. No appropriate national flood datasets were available in Scotland at the time.

A1.4 Comparison of Normal Supply Security Standards with Flooding Resilience

Standards for the design and resilience of the electricity networks are set out in the GB Security and Quality of Supply Standard and Engineering Recommendation P2/6. Although these Standards help to deliver one of the most reliable electricity supply systems in the world, they specifically exclude common mode failure, like flooding, from their standard approach. This is because they do not consider the performance of individual assets and explicitly exclude the loss of busbars (as might occur if a substation were flooded). In view of this it is essential that other organisations ensure that their services are as resilient as possible to the loss of electricity supplies for any reason and that any societal risks are managed through Local Resilience Forums.

All incidents are categorised and reported to Ofgem. The pie chart below indicates the main causes of customer minutes lost (CML) in the ten years between 2005 and 2015.

During the period April 2005 to March 2015 losses of supply due to flooding accounted for approximately 0.7% of the total customer minutes lost. By comparison, other weather related events such as high winds and lightning strikes accounted for some 29%.

In view of this, expenditure to reduce the overall level of customer minutes lost is unlikely to be targeted at flood risk by only taking into account CMLs lost. However the societal impact of electricity supply loss during a flooding incident, in particular the possibility of a large concentration of consumers being disconnected in a single incident, provides a substantive focus for any additional investment to improve resilience to flooding.

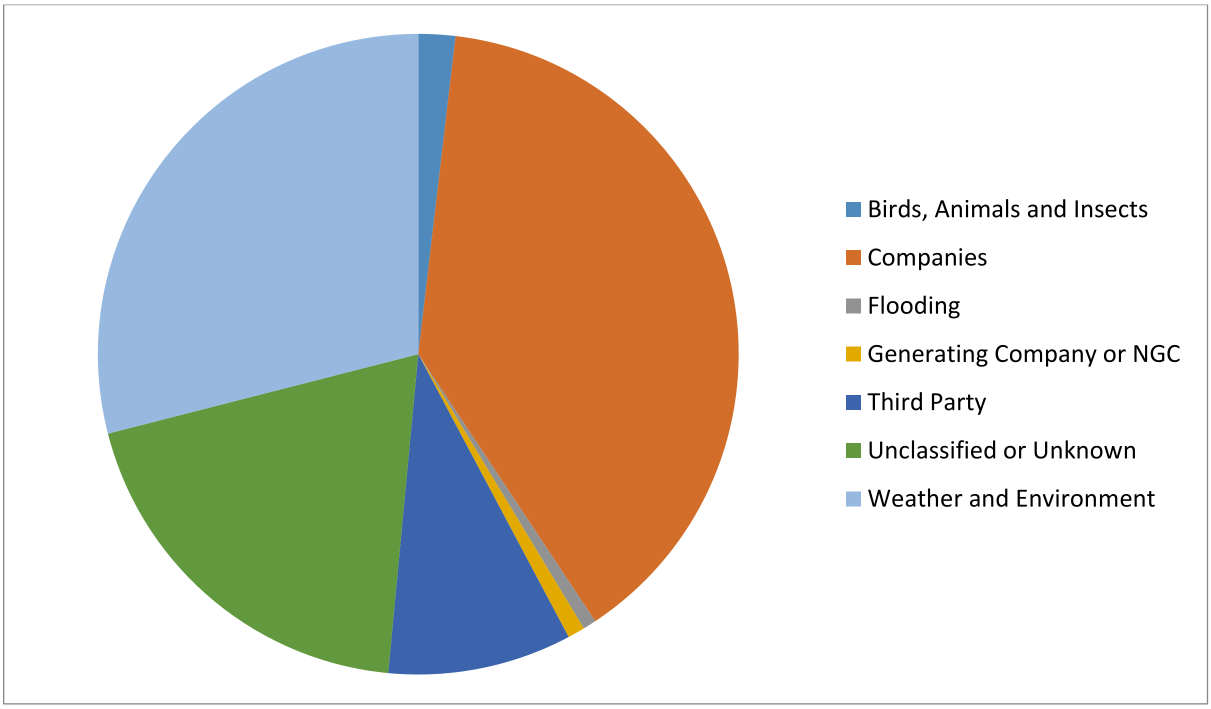


Chart showing all causes of all Customer Minutes Lost (CMLs) from 2005 to 2015

Annex 2 Societal Risk

Experience underlines the particularly severe impact on society of a combination of flooding and loss of electricity supplies to a community, especially if this affects other critical infrastructure.

National policy in this area is set out in the Cabinet Office, Strategic Framework and Policy Statement on Improving the Resilience of Critical Infrastructure to Disruption from Natural Hazards.

Important national infrastructure comprises those sectors which supply essential services to the citizen on which normal daily life in GB depends. These are Energy, Water, Communications, Transport, Finance, Government, Health, Food and Emergency Services. The most important sites, physical assets and information or communication networks within these sectors, whose loss would have a major impact on the delivery of essential services, are deemed the Critical National Infrastructure. A key element of this definition is the concept of 'criticality'. Thus, whether infrastructure is 'critical' should be determined by the impact of its loss on the delivery of essential services and hence people's wellbeing. Distinguishing between critical and non-critical infrastructure in this way enables a risk-based and appropriate approach to work to prevent and prepare for emergencies, including flooding.

As indicated in Section 6 of the main report, the relevant planning standards define a level of resilience to be installed at a given site. In reviewing the reliability of a particular network, it is likely that the risk due to equipment failure / typical weather-related events (high wind, lighting storms etc) at any given site could result in a risk of failure higher than that indicated by the flood risk analysis. However, in understanding the consequence and impact of flooding, not only must the risk of power failure be considered, but also the duration of any failure and the social distress at a time when it's likely that all other critical infrastructure is fully stretched.

The impact of widespread loss of electrical power extends well beyond the immediately obvious consequences. For example, loss of traffic lights can lead to traffic chaos and motorway gridlock, with knock-on impacts on the Emergency Services' ability to respond. Mobile telephony will quickly overload and probably fail completely within six hours. Domestic central heating – even gas fired – will fail as boilers and central heating pumps require power. Water supplies and sewerage will be affected to varying levels. Petrol pumps don't work, cash tills and cash machines fail. Radio and TV broadcasts fail to reach the affected population, as there is no power to for TVs radios or internet. Fires resulting from using candles and asphyxiation from alternate cooking practices indoors become increased risks.

The loss of electricity at any time can be a cause of disruption and annoyance and, depending on the duration, can have a significant impact on consumers wellbeing. In addition, it was noted in the Pitt Review that during the 2007 flooding and at a time when the local community was already distressed:-

“Loss of power caused fear and distress. It meant that people could not get information from the television, radio and internet, and also prevented people from communicating with others, as many modern landline and mobile telephones required power to charge batteries. Loss of power could also cause serious health consequences”.

The 2007 flood events occurred in the summer when the public were not overly reliant on power for heating & lighting. If the flooding had occurred in winter then the consequences of power loss would have been significantly greater.

The floods of winter 2015/16 affecting large numbers of customers in the North of England, particularly in Cumbria and Yorkshire, and demonstrated again the extremely severe impact that flooding can cause for local communities.

It is clear that, in considering the case for investment in flooding resilience at individual substations, great account must be taken of potential societal impact.

Annex 3 Photographs of Electricity Substations

Photograph 1
400kV Transmission Substation

Photograph 2
132kV Grid Substation

Photograph 3
Primary Substation

Photograph 4
Distribution Substation

Photograph 5
132kV Grid Substation: main power conductors at high level

Photograph 6
Primary Substation: low-level conductor in HV switchgear & control wiri