National Grid Flood Resilience Programme

implementing flood resilience protection solutions to ensure continuous operation of essential energy supply infrastructure

by Sun Yan Evans, Tim Lawrence & Mark Brindley

The flood events which occurred in the United Kingdom during the summer of 2007 resulted in a loss of essential services and infrastructure not seen since World War II. Reportedly, over half a million people were left without water or electricity supply, with the estimated cost of the events exceeding £3.2 billion in 2007 prices. The subsequent Pitt Review was commissioned by the Government and outlines a series of recommendations with the objective of improving flood resilience and response measures for the future. The recommendations include those aimed at essential infrastructure services, and highlight the need for the Government and infrastructure operators to work together to build flood resistance and resilience into critical infrastructure assets to ensure continuity of service during extreme flood events.

Walham Substation in Gloucestershire - Courtesy of National Grid

Responding to the Pitt review

National Grid, an international electricity supplier with a major presence in the United Kingdom's energy network, instigated a flood resilience programme in response to the Pitt Review recommendations to ensure that its electricity substations are protected and remain operational during extreme flood events.

Mott MacDonald was subsequently commissioned to assess the flood risk for over 100 (No.) National Grid electricity substations, all of which provide power to between 250,000 and 500,000 people, and where necessary, develop effective flood resilience measures.

Background

Following the widespread flooding in 2007, Sir Michael Pitt recommended that *'the Government and infrastructure operators should work together to build a level of resilience into critical infrastructure assets that ensures continuity during a worst case flood event'.*

One particular example of the flood impacts to essential infrastructure was the damage to Walham Substation in Gloucestershire, which is owned and operated by National Grid. This substation supplies electricity to over half a million people, is a key node in the HV Transmission system, and was almost forced to close due to excessive rainfall and flooding during the 2007 event.

Fortunately, the site remained operational and narrowly avoided losing power thanks to the installation of a temporary barrier and large capacity pumps by the British Army. To implement Sir Michael Pitt's recommendation National Grid has formulated a flood resilience programme for their critical substations across England and Wales.

The UK electrical power distribution system

In the UK, electrical power is transported from power plants to customers via the electricity grid network by transmission and distribution network owners. The transmission system typically operates at 400kV or 275kV (132kV in Scotland), whereas the distribution system operates at voltages from 132kV to the normal household voltage of 230kV. The 400kV and 275kV substations each service more than 250,000 people.

There is also a high level of interdependence between core infrastructure sectors, and the energy sector is at the very top of this interdependency chain. Many existing substations are located in floodplains, and if they are flooded, there would be direct and far-reaching impacts on people's lives and the economy.

Failure of the electricity or energy supply would propagate and cause cascade failures to dependant services. Core infrastructure sectors such as water supply, health care, transportation, communication as well as emergency services would not function without the continuous supply of electricity.

As a significant number of people and core infrastructure services are reliant on electricity substations, there are also legal obligations to keep these substations operational at all times. With this in mind, there is a real need to protect these sites against the risk of flooding.

Mott MacDonald has been tasked to assess the National Grid's critical substations up to the 1 in 1000 year flood event and with consideration of climate change over the next 50 years.

Where substations have been identified as being subject to flooding under extreme events, flood defence solutions have been successfully developed which will help ensure that the supply of electricity to the public is maintained, while the impact of proposed flood defences on third parties is kept to a minimum.

Flood risk assessment

The flood risk assessments for National Grid substations have been undertaken in two phases. A staged approach was adopted to ensure that site studies are progressed according to 'risk based' site selection:

- Phase 1 – 38 (High Risk) Substations.
- Phase 2 – 79 (Medium Risk) Substations.

As part of these assessments, Mott MacDonald undertook hydrological and hydraulic modelling, assessing flood risk from all sources, such as:

- Fluvial flooding.
- Tidal flooding.
- Pluvial flooding (surface water).
- Groundwater.
- Flooding from sewers and drains.
- Flooding from reservoir failure.

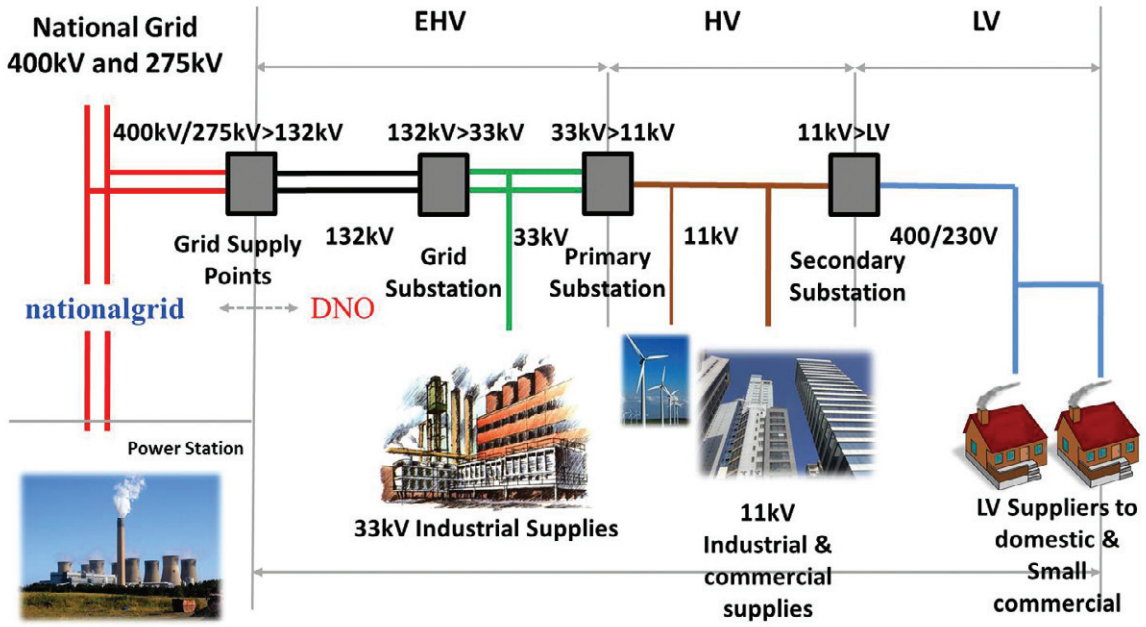
For many sites, detailed hydraulic modelling consisting of 1D and 2D numerical modelling is required, including breach and overtopping analysis, wave run-up, storm surge, blockage scenarios and climate change.

For each assessment, National Grid and Mott MacDonald work closely with relevant stakeholders including the Environment Agency at both national and regional levels, Natural Resources of Wales, local authorities and Internal Drainage Boards to develop the most sustainable resilience solutions which will protect the site but also have minimal impact on third parties.

Each assessment has been carried out in accordance with the latest requirements and recommendations relevant to the location of the substation - for England, the National Planning Policy Framework

Walham Substation during the 2007 floods
Courtesy of National Grid

Walham Substation with flood protection wall
Courtesy of National Grid



UK Electricity supply network diagram - Courtesy of National Grid

(NPPF) published in 2013, and for Wales the Technical Advice Note (TAN 15): Development and Flood Risk, published in 2004.

National Grid has also prioritised the investment, i.e. first protecting those substations at risk from the 1 in 100 year flood event, then those at risk from less frequent flood events, such as the 1 in 200 year and 1 in 1000 year flood events.

The target resilience design standards for National Grid infrastructure are identified in Engineering Technical Note 138 (ETR138) and as outlined in the National Grid Flood Mitigation Policy PS(T)095.

- National Grid's target level of protection for substations is for the 1 in 1000 year flood event plus climate change plus 300mm freeboard.
- Where this is not achievable, National Grid's minimum level of protection is the 1 in 200 year flood event plus climate change plus 300mm freeboard.

Flood resilience implementation and achievement

A sequential approach was used throughout the process in identifying and developing suitable flood resilience measures, also with the aim of minimising impact on third parties:

- Can the power be supplied from elsewhere or can the site be relocated away from flood risk?
- Can the existing equipment be raised above flood levels?
- Can the existing equipment and key apparatus be protected locally?
- If a flood defence must be built around the entire site, can it be designed to the minimum footprint?
- Access and egress were taken into consideration, as well as operability of the site, to ensure that site operators and staff can safely and efficiently operate the site while also benefiting from increased flood resilience.

At National Grid substation sites, there are a variety of critical assets and equipment that must remain operational to ensure continuity of supply. Therefore, the equipment must be protected against damage by flood water up to the target level of the 1 in 1000 year flood event or the minimum level of the 1 in 200 year event (with considerations for climate change conditions).

Flood resilience solutions may consist of one or more of the following:

- Whole site protection.
- Raising or moving critical equipment.
- Localised protection, such as building hardening or bunds around equipment.
- Drainage diversions.
- Embankment bunds.

Whole site protection ensures that the entire operational area remains protected and without hazard from floodwaters and involves the construction of a hard flood wall around the perimeter of the site. This flood resilience solution was employed at Walham Substation, where construction works started in July 2012 and were completed in August 2013.

Construction of Walham Substation flood defences

The construction of a whole site flood protection wall consisted of steel piles driven into the ground around the 1km perimeter of the site to form a base for the defence wall. Next, a cast concrete flood wall between 1.6 and 1.9m in height was built to protect the site from flooding for the 1 in 1000 year event with an electrified palisade fence on top for security. Five new pumping stations were also installed to address the potential seepage or any residual ingress of floodwaters.

During construction of the flood defence, water levels were close to inundating the site a number of times and the defence wall has been tested by a low level flood following completion.

The Walham Substation Flood Defence Project subsequently won multiple awards, including the Institution Of Civil Engineers (ICE) Project of the Year award in 2014 and the RICS Infrastructure Project of the Year 2015. Mott MacDonald is very pleased to be able to play a part in this important and high profile scheme, including flood risk assessment, developing resilience solutions and undertaking scheme design.

Whole site protection is not always the best flood resilience solution and can often result in third party impacts due to a loss of floodplain storage and the redirection of floodwaters. Provided that critical equipment remains unaffected by floodwaters, the site can remain operational even if the remainder of the site is subject to flooding. As part of the assessments, Mott MacDonald determine the threshold levels at which all critical equipment on-site is not impacted by floodwaters.

Subsequently, Mott MacDonald develop flood resilience solutions by considering options to raise equipment or implement localised protection which ensure continuity of the supply of electricity while removing or minimising the risk of impact on third parties that are a result of the flood defence measures. If the impact on third parties can be kept to a minimum, Mott MacDonald also prescribes flood defence solutions that involve diverting floodwaters via diversion channels and embankments.

Progress of the Flood Resilience Implementation Programme

National Grid is now half way through the 14 year Flood Resilience Implementation Programme which started in 2008. Many of the National Grid substations are now resilient to flooding. Walham Substation is one of them. More substations are yet to be protected against extreme flood events by the end of this programme in 2022.

So far, huge achievements have been made through clear vision, strong leadership, determination and commitment by National Grid, as well as through fantastic collaboration and partnership working between National Grid, the Environment Agency, numerous local authorities and Mott MacDonald.

Conclusions

Protection of essential infrastructure, such as electricity substations, from the risk of flooding is critical. The dependence of other core infrastructure services such as the health, communication and transportation sectors, as well as the large number of people at risk of losing power and functionality, mean that ignoring the potential flood risk at these substations is not an option.

National Grid, in partnership with Mott MacDonald, has successfully identified the flood risk at its electricity substations and has subsequently constructed over a dozen flood resilience solutions including using modern technology, innovative solutions and novel techniques, to protect against extreme flood events, while continuing to implement many more across England and Wales.

One of the major outcomes of this flood resilience programme is that the successful delivery of flood defence solutions will help to ensure that the supply of electricity to the public is maintained, whilst ensuring the impact of these flood defences on third parties has been kept to a minimum.

While Mott MacDonald has been developing flood resilience solutions for the energy sector, it is also important to understand the standard of protection in the infrastructure dependency chain, and to ensure that dependant core infrastructure is also resilient. The standard of protection for all core infrastructure sectors, not only for the energy sector, needs to guarantee that these key services can remain functional when flood events do occur.

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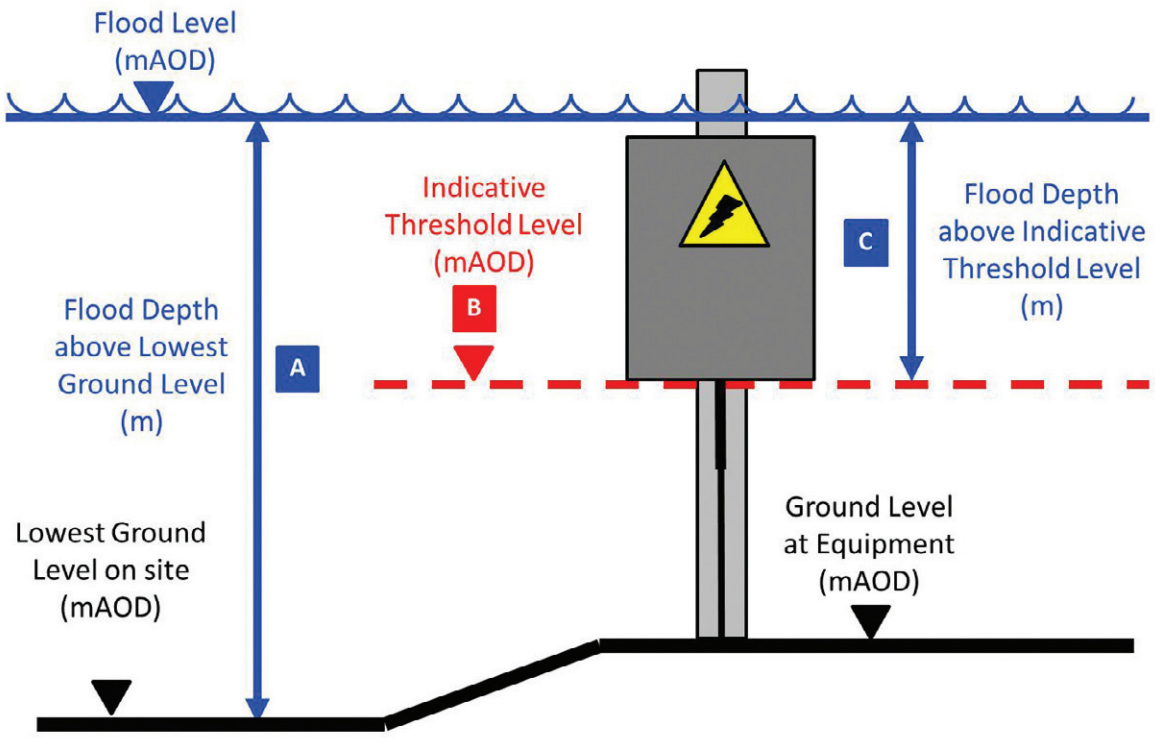

Assessment of substation critical equipment levels - Courtesy of Mott MacDonald)