Department for
Business, Energy
& Industrial Strategy

GB POWER SYSTEM DISRUPTION – 9 AUGUST 2019

Energy Emergencies Executive Committee: Interim Report

September 2019

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Executive Summary

Following on from the Friday 9th August power disruption in Great Britain the Secretary of State for Business, Energy and Industrial Strategy commissioned the Energy Emergencies Executive Committee to undertake a comprehensive review of the incident and submit a report which identifies lessons and recommendations for the prevention and management of future power disruption events. We also promised to publish this interim report.

The Energy Emergencies Executive Committee is a partnership between government, the regulator and industry which co-ordinates resilience planning across the energy industry. It ensures a joined-up approach to emergency response and recovery, identifying risks and processes to manage the impact of emergencies affecting the supply of gas and/or electricity to consumers in Great Britain.

On 9th August, over 1 million customers were affected by a major power disruption that occurred across England and Wales and some parts of Scotland. Though the power disruption itself was relatively short lived – all customers were restored within 45 minutes - the knock-on impacts to other services were significant. This is especially true for rail services which experienced major delays that extended into Sunday 11th August.

The energy regulator, Ofgem, has launched an investigation into the incident which will focus on lessons learned for the industry and, in particular, on the performance of National Grid Electricity System Operator (ESO), National Grid Electricity Transmission, Distribution Network Operators (DNOs) in England and Wales and the two generators involved – RWE Generation (Little Barford Power station) and Orsted (Hornsea). This investigation by Ofgem is ongoing and any resulting enforcement action is a matter for them.

Alongside this investigation, E3C has identified, through this interim report, a set of areas that we believe merit further investigations now in order to learn lessons from such an event, and in order to make the electricity system more resilient. We plan to build on these emerging findings in the coming weeks and provide a set of recommendations to the Secretary of State. We intend to publish the final report including these recommendations alongside the outcome of Ofgem's investigation by early November.

This interim report has been informed by discussion with National Grid Electricity ESO, Electricity Transmission Operators, DNOs, generators, Ofgem and essential service providers such as Network Rail. It provides a timeline of events that led to the power disruption on 9th August, the response of the electricity system, an outline of the impacts to other services as well as a discussion of emerging issues and next steps. The data presented in this report has been provided by the above parties.

The initial findings from the ESO's Technical Report of 6th September show that the incident is thought to have been caused by a lightning strike to an overhead transmission line and the near simultaneous loss of a number of generators at approximately the same time. [1]

The system response held at the time of the incident was 1,000MW. However, the total generation lost from the affected power stations, as part of the initial event, was in the region of 2,100MW, greater than the response held. This loss caused the system frequency to drop below the statutory limit of 49.5Hz to 48.8Hz.

Once the frequency of the system hit 48.8Hz, an automatic protection system known as Low Frequency Demand Disconnection (LFDD) stage one was triggered, which had the effect of disconnecting approximately 973MW of demand (over 1 million customers), to arrest the fall in frequency. This was shared out across the different Electricity Distribution Networks in England and Wales. However, the ESO Technical Report states that approximately 600MW of embedded generation was also disconnected *at this point*, either as part of the LFDD scheme or via another mechanism, resulting in a net reduction in demand of 350MW.

The ESO Technical report says that frequency was restored to normal operating conditions within 5 minutes of the initial lightning strike and all disconnected customers were restored within 45 minutes. That said, a number of services experienced knock-on disruptions as a result of the power disruption, notably in the rail transport, health, water and oil sectors.

This interim report has identified the following emerging areas that we recommend to the Secretary of State need further investigation before submission of the final report early in November:

- Communications, notably in the first hour of the response needs to improve, and this has been recognised by the ESO technical report (6th September 2019). Communication policies and protocols across the ESO, DNOs, Transmission Operators, generators, Government, Ofgem, the Energy Networks Association (ENA) and Energy-UK should be reviewed to understand whether these support timely and effective communication for future events. This will crucially help to manage impacts on the public.
- Given the loss of generation, we suggest that more work needs to be done on the compliance process, most notably for embedded generation. There should be a review of the timescales for delivery of the Accelerated Loss of Mains Change Programme to reduce the risk of inadvertently tripping and disconnecting embedded generation. National Grid has stated that the situation was not caused by a systemic risk in wind; further work is required from the electricity sector to ensure continual balance between system security, resilience and the generation mix.
- We recommend that there should be a review into the reserve and response holding policy of the ESO and whether it is fit for purpose going forward. In particular, this should explore the single largest loss criterion and whether this adequately covers the consequential loss of embedded generation; the increased volatility of frequency deviations within operational limits; and the level of inertia.

[1] NGESO Final Technical Report into Friday 9 August Power Outage, https://www.nationalgrideso.com/information-about-great-britains-energy-system-and-electricity-system-operator-eso

- To ensure lessons are learnt a review into the performance of the LFDD scheme is required. Although the LFDD scheme worked to arrest the frequency fall in stage 1 of its implementation, we should consider a mechanism to inform essential services on the LFDD scheme in order for them to manage disruptions. Allied to that, for essential services, it would be appropriate to establish minimum standards for critical infrastructure to ensure that their internal systems and business continuity plans are fit for purpose for such situations.

Power Disruption Timeline 9th August

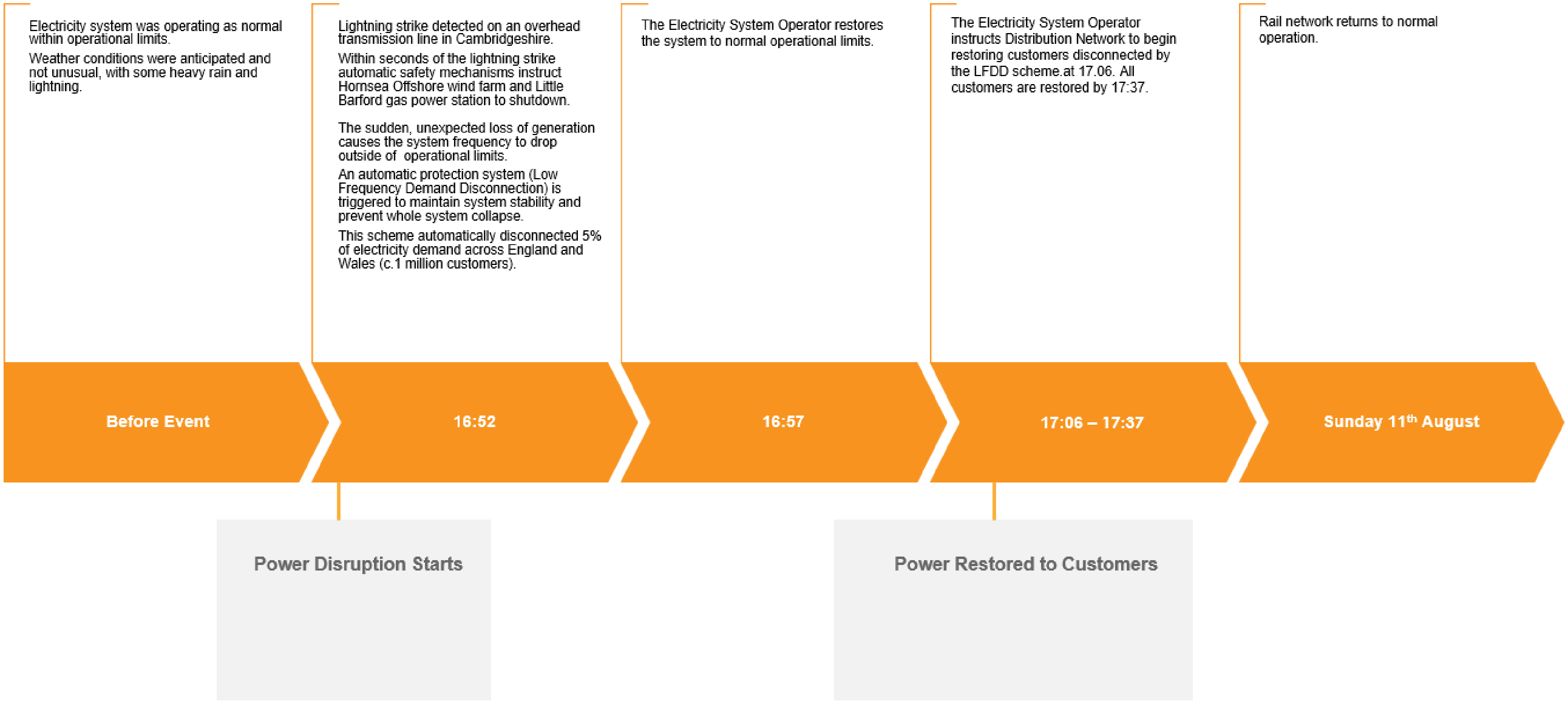

Figure 1: Timeline representing the sequence of events related to the 9th August power disruptions.

Electricity System Response

National Grid Electricity System Operator (NGESO)

Reserve

The ESO is required to hold sufficient additional generation in reserve so that in the event of an unexpected loss of electricity supply or demand, there is sufficient on standby to replace it. The quantity it is required to hold[2] must cover the largest fault that could credibly occur on the network which generally correlates to the loss of the single largest generator exporting power to the grid at that time.

The ESO has the flexibility to hold more reserves during adverse weather conditions, however at the time of the lightning strike, the ESO was holding 1,000MW of reserve generation, matching the largest infeed on the event day.

Frequency Response

The ESO is also required to ensure that the frequency of the electricity system remains within a narrowly defined range (between 49.5Hz – 50.5Hz) to maintain system stability and prevent a full system collapse.

The sudden, unexpected loss of a large generator would result in a deviation of system frequency and the ESO holds frequency response in the form of additional generation, energy storage and large customers, who monitor the system frequency and automatically adjust their supply or demand to keep the frequency within the defined range.

The amount of frequency response that the ESO is required to hold must cover the frequency deviation expected from the most onerous loss of power infeed that could occur, which is typically the loss of the largest single generator exporting power to the grid at that time.

At the time of the lightning strike, the ESO indicated through the ESO Technical Report that they were holding sufficient reserves to deal with the 1,000MW power loss, comprising 1,022MW of Primary Frequency Response (capable of responding within 10 seconds of an incident).

National Grid Electricity Transmission (NGET)

The ESO Technical Report states that at 16:52, lightning struck a 400kV overhead transmission line in Cambridgeshire; this was one of several lightning strikes that hit the National Electricity Transmission System (NETS) that day, but the only one that had any impact. Lightning strikes are a regular occurrence on the NETS and there are

[2] The amount of generation reserve that the ESO must hold at any time is set out in the Security and Quality of Supply Standards (SQSS) which sets out the criteria for planning and operating the GB Transmission System.

automatic systems in place to clear any subsequent faults and return the transmission line to normal operation.

Generators

The lightning strike was followed by the near simultaneous generation loss in the region of 2,100 MW comprising:

- Loss of generation embedded in the Electricity Distribution Network, consisting of small-scale renewables and diesel farms. Automatic safety systems shut down the plants to protect equipment in response to the disturbance detected on the electricity system.
- Loss of generation at Hornsea One offshore windfarm was also lost after experiencing an unusual voltage fluctuation coincident with the lightning strike. Though the windfarm's onshore control system performed as expected, the offshore system did not, leading to automated safety mechanisms to shut the windfarm down. The operator has identified the issue with the offshore control system and taken action to prevent a reoccurrence of this event in similar circumstances.
- Loss of generation at Little Barford was lost in three stages over a minute and half. The steam turbine was shut down by an automatic scheme, followed by one of the gas turbines around a minute later. The power station staff then took the decision to shut down the remaining gas turbine 30 seconds later to protect the station. Investigation into the cause of the shutdown is ongoing.

Fall in System Frequency

The ESO Technical Report says that the cumulative loss of Hornsea One Windfarm, the steam turbine at Little Barford Station and local embedded generation exceeded the reserve and response being held by the ESO, which was 1,000MW. As a result, the frequency of the electricity system began to fall and Frequency Response systems were automatically triggered, arresting the frequency at 49.1Hz.

The System frequency began to recover however the additional loss of the Little Barford Gas Turbine (210MW), caused a second drop in system frequency to 48.8Hz; this triggered the operation of an automatic protection system known as Low Frequency Demand Disconnection Scheme (LFDD).

This protection system enabled the frequency to recover to 48.9 Hz before the loss of the second gas turbine at Little Barford (187MW). Over the next three minutes NGESO instructed an additional 1,240MW of reserve and frequency response to restore the frequency back to 50Hz. The electricity system was restored to normal operating parameters within 4 minutes and 42 seconds of the initial lightning strike. Figure 2 provides an overview of the system frequency over this timeframe.

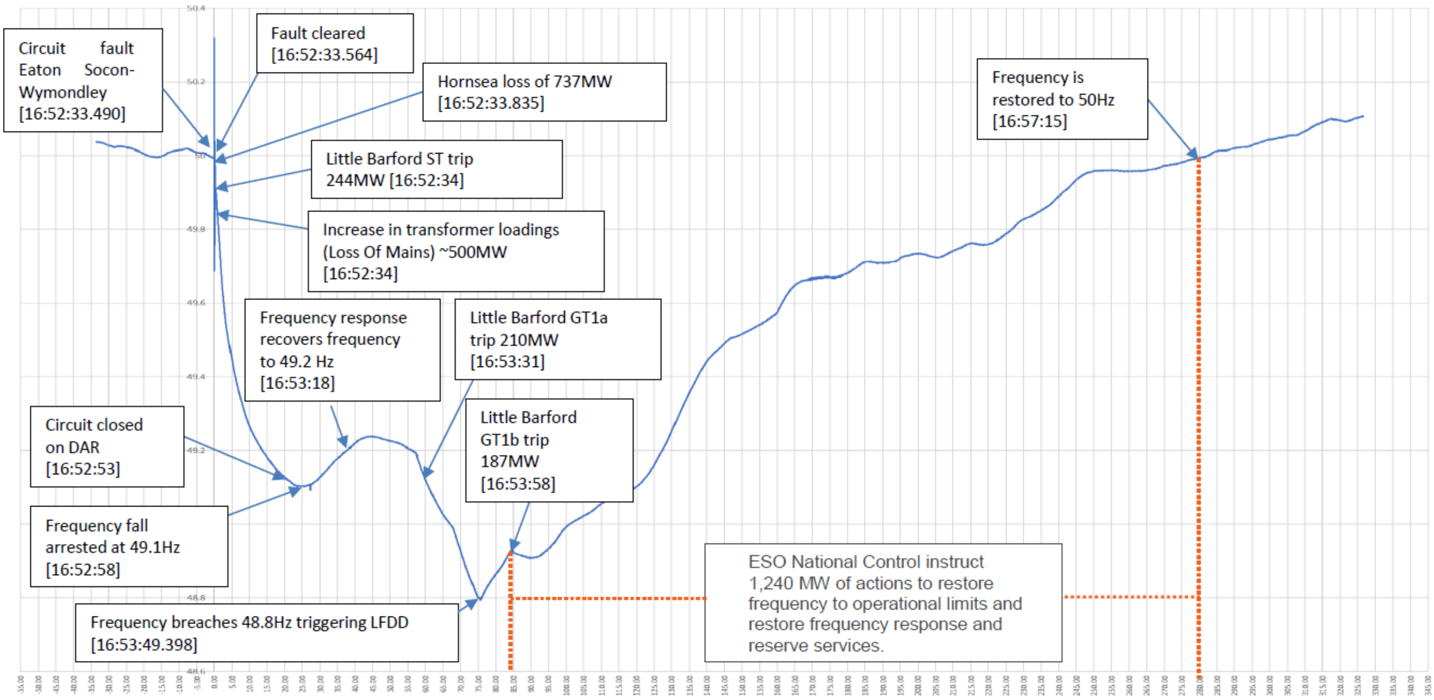

Figure 2: Graph showing system frequency during the power disruption. Taken from the National Grid ESO Technical Report 06/09/2019.

Electricity Distribution Network Operators (DNOs)

To balance the shortfall of electricity generation and its effect on system frequency, an automatic protection scheme known as Low Frequency Demand Disconnection (LFDD) is installed on the distribution network. This scheme is designed to disconnect between 5 - 60% of total peak demand through 9 stages as the system frequency reaches certain trigger levels. The disconnected demand is designed to be spread equally across all Distribution Networks in England and Wales

In the ESO Technical Report, at 16:52, stage 1 of LFDD was automatically triggered when the frequency collapsed to the stage 1 frequency setting. As a result, 973MW of national electricity demand was automatically disconnected, equating to just over 1.1m customers. However, we note that the net effect of loss of supply to over 1 million consumers was only 350MW. While this enabled the system to recover on this occasion, reasons why further distributed generators tripped off at this time need to be thoroughly investigated and understood to ensure that the LFDD operates as intended if ever needed in the future.

Reporting DNO	License Area	MW of disconnected demand by LFDD	Customers Affected	Final Restoration Time of Demand
Scottish Hydro Electric Power Distribution (SHEPD)	-	0	0	-
Scottish Power (SP)		22	23,117	16:59
Northern PowerGrid (NPG)	North East	76	93,081	17:18
	Yorkshire	14	10,571	17:12
Electricity North Limited (ENW)	-	52	56,613	17:17
SP Manweb	-	130	74,938	17:15
Western Power Distribution (WPD)	East Midlands	122	150,445	17:25
	West Midlands	190	187,427	17:37
	South Wales	36	29,060	17:11
	South West	12	110,273	17:22
UK Power Networks (UKPN)	Eastern	69	79,390	16:56
	London	174	239,861	17:37
	Southern	69	81,358	17:15
Southern Electric Power Distribution (SEPD)	-	7	16,744	17:07
Total		**973**	**1,152,878**	**17:37**

Table 1 Low Frequency Demand Disconnection reported by DNO area.

Post event, two DNOs reported that a number of LFDD stage 1 schemes did not trigger, and therefore did not disconnect demand. This could be due to:

- the system frequency did not stay at 48.8Hz long enough to trigger the operation of all LFDD schemes or;
- the +/-0.01Hz tolerance setting on the LFDD schemes which meant that when the system frequency fell to 48.792Hz, not all schemes were triggered.

Additionally, disconnections were also experienced in Scotland where LFDD Stage 1 schemes are meant to be triggered when the system frequency falls to 48.5Hz. It has been confirmed that this was due to incorrect LFDD settings that have subsequently been corrected.

The automatic operation of the LFDD scheme successfully arrested the falling system frequency as intended and by 17:06 the electricity system operator had reported that the system had returned to its normal stable operating position, and instructed DNOs to restore the disconnected demand. All demand was restored by 17:37, within 45 minutes of the initial lightning strike.

Impact on Essential Services

The disconnection of over 1 million customers caused knock-on impacts across several other services. Most of this demand would have been disconnected as a result of the LFDD scheme, however other services may have experienced varying levels of disruption due to their own automatic safety systems or business continuity measures, not specifically as a result of power being disconnected. These measures are not operated by the ESO or DNOs and are managed independently.

Further work between the ESO, DNOs and affected customers is required to understand the cause behind the disconnections, however our current understanding of the impacts is set out below; recognising that investigations are all ongoing.

Rail

The Department for Transport confirmed that rail commuters experienced significant disruption due to a safety mechanism built-in to all operational Class 700 and Class 717 Desiro City trains. This detected the drop in frequency on the electricity system which triggered 60 trains to shut down in order to protect the onboard systems and electronics.

While around half of the affected trains were restarted by their drivers, the rest required engineers to be dispatched, blocking tracks and causing huge disruption on lines into St Pancras International and King's Cross. 371 services were cancelled and 873 delayed, despite these trains being unaffected by the power issues, and disrupting thousands of customers journeys. This led to St Pancras International, King's Cross and Euston stations having to limit passenger numbers entering the stations at various times.

Due to the level of disruption throughout the evening, a number of trains did not end up in their correct location at the end of the day, which led to some early morning services on Saturday 10th August being disrupted.

The Class 700 and 717 trains, have been introduced over the last three years and a separate investigation is being conducted by the train operating companies and manufacturer to discover why the new trains were so badly affected by the outage and how to minimize the impact of any similar incidents in the future.

Health

A DNO confirmed to us that two hospitals were affected by LFDD with their back-up generation working as designed. Another hospital was affected by the fall in frequency/voltage excursion, despite not being disconnected as part of LFDD. This was due to incorrect protection settings on the hospital's own network, which resulted in the site switching over to back-up generation and one of its 11 generators failing to operate.

Water

Approximately 3,000 people experienced water supply disruptions due to booster water pumping stations failing to automatically switch over to back-up power supplies. Some of these customers would have experienced a temporary loss of running water in their homes, but others would have remained unaffected due to water storage in the system allowing running water to continue. The majority of customers were restored within 30 minutes.

Energy

An oil refinery has confirmed to us that it was disconnected as a result of the site's system which detected a drop in frequency and disconnected the plant to protect on-site equipment. The refinery operations team utilised the site's emergency procedures and automated systems to safely shutdown portions of the plant however, due to the complexity of restarting large process units it took a few weeks to restore normal operations.

It is worth noting that the gas networks and transmission operator reported to us that they implemented their response mitigation plans in a timely way; response planning that looks at electricity-gas interaction should continue to be a feature of the system.

Airports

DNOs have confirmed to us that two airports, one in the Midlands and one in the north of England, were impacted by the power disruption. One airport was impacted as a result of LFDD stage 1 being automatically triggered. The airport had its own standby generation for its safety critical systems and power was restored via the distribution network after 17 minutes. The second airport, unaffected by LFDD, switched to-back up power supplies without issue and was restored within a few minutes. A fault with its on site internal network meant that power to some services (check-in hall, central security search, hold baggage screening, and some telephony and comms systems) was delayed for up to 50 minutes.

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Industry and Public Communications

Industry communications to customers is a key area to consider as part of this review process. Communication and engagement with both the public and media during an emergency response is a critical function and it is vital that external communications are co-ordinated, consistent, clear and timely. Notably, there needs to be clear and regular communications with the public, key services and other stakeholders when there are power cuts. There also need to be good lines of communication between key industry partners, such as BEIS, the ESO, DNOs, Transmission Operators, generators, electricity suppliers, the gas industry and the Energy Networks Association (ENA).

For a visual representation of the communications on the 9th August please *see Public Facing Comms* diagram on page 15.

Pre-event

A stronger shared understanding of national electricity-related scenarios should improve stakeholders' awareness of disruptions, including the procedures related to the automatic deployment of the Low Frequency Demand Disconnection (LFDD) scheme. Local Resilience Forums (LRFs) are responsible for managing the response in local areas from a civil contingency perspective. LRFs indicated that there is an ongoing need to work with critical customers (such as hospitals and key transport hubs) to ensure a shared knowledge of the likely disruptions caused by LFDD and highlight where disruption can be mitigated through stronger business continuity planning.

During an event

Many communications to the public related to the power disruptions were sent by Twitter due to the platforms capability to reach large audiences in a short timeframe, and for external media channels to pick up announcements. DNOs led local public communications during the event and the ESO did not publish public statements until after the disruption, meaning that energy partners (such as generators) were not directly informed. In parallel with social media, DNOs reached out to customers via text message alert services and telephone services between 17:02 and 18:30. DNOs also fielded staff for media enquiries. Given the fast-paced nature of the event this may prove to have been the best means of communication to customers. Updates from the ESO followed the first set of restorations and were not publicly released until 18:27 via Twitter.

One of the significant issues raised following on from the 2013 Christmas storms was that customers did not easily know how, or who, to communicate with during a power supply outage. Between 16:00 and 18:00 on 9th August, the ESO Technical Report states that 39,568 calls were made to the 105 Single Emergency Number, a facility introduced since the Christmas 2013 event and managed by the ENA on behalf of members. This is a clear indication that the lines of communication between customer and DNO during an emergency or safety-related event have been improved.

Post–event

The Secretary of State for Business, Energy and Industrial Strategy later announced via Twitter (10th August) and GOV.UK (14th August) that the government was to commission the Energy Emergencies Executive Committee to provide an interim and extended report into the power disruptions.

Public-facing Comms 9 August

9 August 17:02 – 18:30
DNOs begin contacting customers via telephone, text messages and social media to acknowledge the power disruptions.

17:17-19:00
Distribution Network Operators field external media inquiries from BBC News, Channel 5 News, The Financial Times, The Times and The Guardian.

17:30
National Grid's press office informed Distribution Network Operators that they handle media enquiries for this event.

18:27
First statement from the ESO confirmed that whilst 2 generators had disconnected the system was now functioning properly.

20:06
Second statement from the ESO explained why there had been a power cut and confirmed that the system had been restored at an NTS and DNO level.

Distribution Network Operator Tweets: *(examples not exhaustive)*

National Grid Comms:

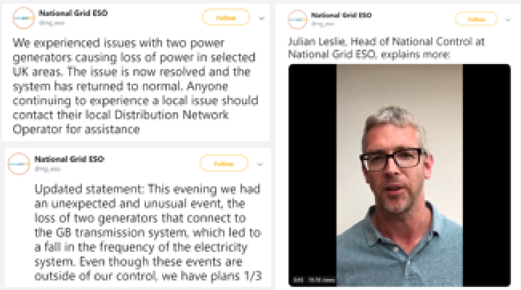

Figure 3: Public-facing comms during the power disruptions on the 9th August.

Areas of Emerging Interest and Next Steps

We recommend that the Secretary of State considers the following areas of emerging interest for further investigation:

The Loss of Generation

Although the loss of Hornsea One Windfarm, Little Barford Power Station and the embedded generation were coincident with the detected lightning strike, investigations are still ongoing. Further work is required to understand the exact failure mechanisms and whether these can be mitigated.

There are also wider questions with regards to the compliance process for embedded generation and whether this is fit for purpose as we move towards a more decentralised energy system. In particular, there is a case for review of the timescales for delivery of the Accelerated Loss of Mains Change Programme to reduce the risk of inadvertently tripping and disconnection of embedded generation as Great Britain moves to ever increasing levels of embedded generation.

The Evolving Generation Mix

In the last decade the generation mix has moved to include a greater amount of electricity generation from renewables and interconnection from Europe. These energy sources are different to the conventional electricity generation sources, in that they do not provide the system with inertia. This means that there is a risk that in the event of a fault or disturbance on the electricity system, the frequency drops more quickly, as inertia resists to the rate of frequency fall. However, also in this period, newer forms of generation and new responses from existing generators provide options for the system operator to protect against this risk. To achieve the energy system which the government and industry aims to provide, further work is required from both generators and the ESO to ensure a continual balance between system security, resilience and the generation mix.

Reserve and Response Holding

Analysis into whether the reserve and response providers procured by the ESO, delivered their contracted requirements within adequate timeframes is ongoing and the outcome of this will help form a view as to whether the planning assumptions used by the ESO to calculate how much reserve or response they contract need reviewing.

Broader questions have been raised as to whether the response and reserve holding policy, outlined in the security standard and codes are fit for purpose going forward. In particular, exploring the single largest loss criterion; whether they adequately cover the consequential loss of embedded generation; the increased volatility of frequency deviations within operational limits; and the level of inertia.

Low Frequency Demand Disconnection (LFDD)

We note that the net effect of loss of supply to over 1 million consumers was only 350MW. While this enabled the system to recover on this occasion, reasons why further distributed generators tripped off at this time needs to be thoroughly investigated and understood to ensure that the LFDD operates as intended if ever needed in the future. Also, DNOs reported that some of the stage one schemes did not trigger, therefore, not all the demand allocated to LFDD stage 1 was disconnected and as stated earlier in this report, there are a number of potential reasons for this. To ensure lessons are learnt a review into the performance of the LFDD scheme is required. This will help to ensure there is a consistent view in the application of LFDD across electricity network operators.

Several essential services were affected by the power disruption and a further review is required to identify essential infrastructure that is currently connected to the LFDD, understand why they have been included in the scheme and whether it is possible to modify the LFDD scheme to minimise impacts to essential services.

Further work is required to develop a shared understanding between electricity network companies and essential services of how electricity disruptions affect the services that people rely on every day. In particular, where these services are placed on schemes such as LFDD, there should be a mechanism in place to inform them of the potential risk and ensure that owner/operators of such services put in place appropriate mitigations to manage disruptions.

Essential Services

Services were disrupted due to their own automatic safety mechanisms or business continuity plans; these were facilities that were not disconnected by LFDD in this event. More work is required to understand the root cause behind these disconnections and whether it would be appropriate to establish standards for critical infrastructure and services setting out the range of events and conditions on the electricity system that their internal systems and business continuity plans should be designed to cater for.

Communication

Communication policies and protocols across the ESO, DNOs, Transmission Operators, Generators, Government, Ofgem, ENA and Energy-UK should be reviewed to understand whether these support timely and effective communication for future events.

Next Steps

A final report is due to be submitted to the Secretary of State at the beginning of November. In the interim, this review will continue to work on the issues identified above to identify lessons learned and recommendations for the prevention and management of future power disruption events. For comments or questions, please email ercorrespondence@beis.gov.uk

Annex A: Electricity Networks Diagram

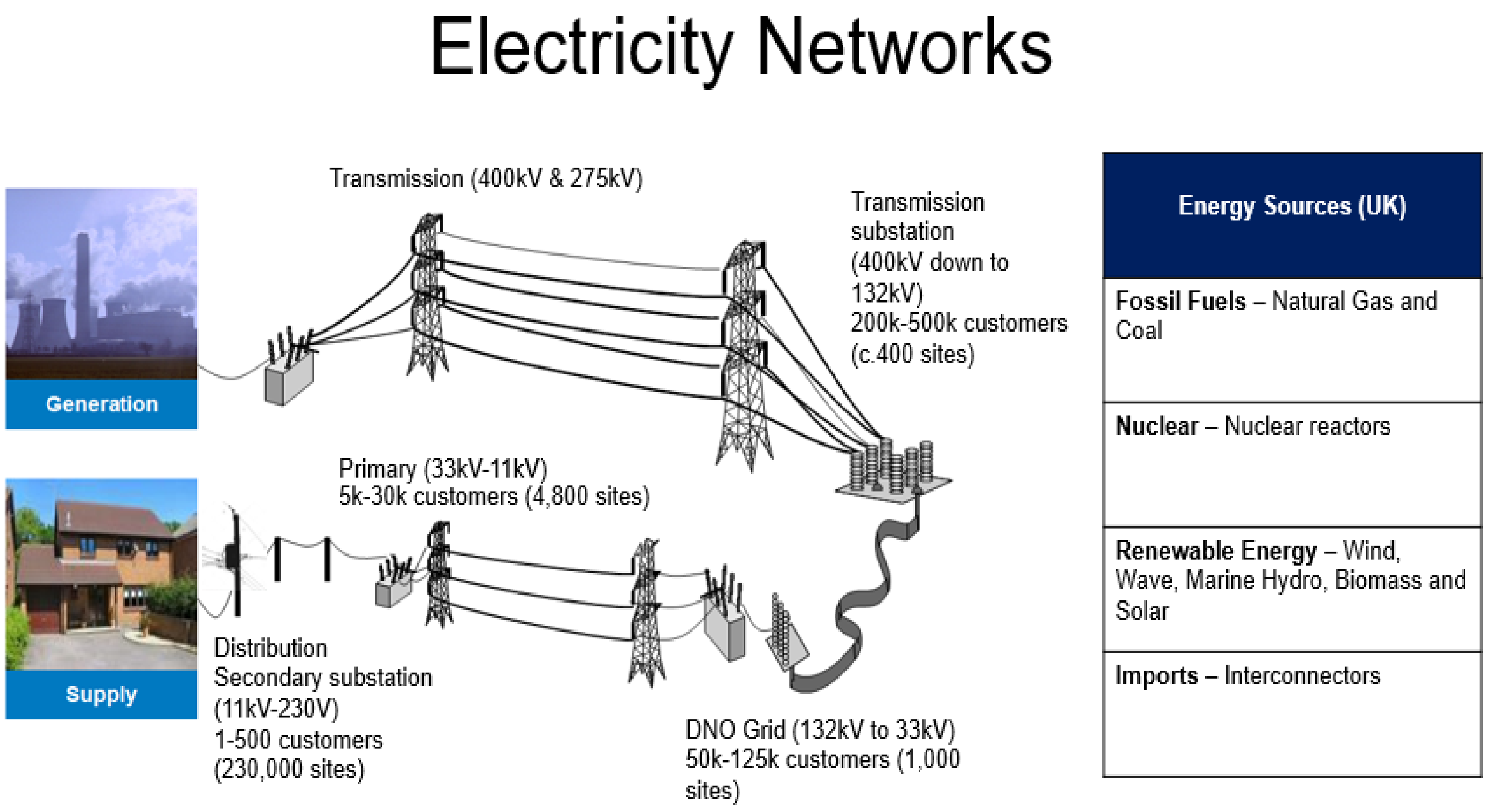

Figure 4: Diagram representing the GB power system.