North Hyde Review Final Report

30 June 2025

NESO
National Energy System Operator

Contents

Introduction

1. Foreword

1.1 Energy plays a crucial role in all our lives, for our homes, businesses, and economy. From the energy that runs into our homes, schools and hospitals, to the servers that power our internet, having a strong and resilient energy system is essential.

1.2 We have seen the impact of the recent outage in the Iberian Peninsula and the serious impact this had on the people in this area and their economies. We have seen the targeting of energy infrastructure during conflicts across the globe – both past and present. Keeping our energy infrastructure safe, secure and in good working order has never been more important.

1.3 In Great Britain, we have one of the most reliable energy systems in the world, with comparatively few supply disruption events affecting consumers. However, no matter how low the likelihood, disruptions still occasionally occur.

1.4 On Thursday 20 March 2025, a power outage occurred at North Hyde 275 kilovolt (kV) electricity substation, near Hayes in West London ("the incident"). The power outage led to the loss of supply to over 70,000 domestic and commercial customers, including Heathrow Airport.

1.5 As the National Energy System Operator (NESO), we were commissioned by the Secretary of State for Energy Security and Net Zero ("the Secretary of State") and Ofgem to review the incident, to identify lessons and recommendations for the prevention, and management, of future power disruption events; and to identify lessons for Great Britain's energy resilience more broadly.

1.6 On Tuesday 6 May 2025, this review published an interim report which established the timeline and sequence of events of the outage, the roles and responsibilities of the key stakeholders involved, and outlined areas of further investigation.

1.7 In this final report, this review presents the root cause of the incident, explains why the power outage occurred, and provides recommendations for improving the resilience of essential services, including Critical National Infrastructure (CNI), to energy disruption in the future.

1.8 We would like to thank all stakeholders for their cooperation and timely provision of information and evidence to support this review. By working collaboratively to review the incident and identify recommendations for the future, we are now in a stronger position to strengthen the resilience of Great Britain's energy system.

2. Executive summary

2.1 **On Thursday 20 March 2025 at 23:21, one of three supergrid transformers ("SGT3") at North Hyde 275kV substation and its associated circuit, connecting it to the wider transmission system, tripped. SGT3 was later confirmed to have caught fire. Shortly after, the adjacent transformer ("SGT1") also tripped, resulting in the simultaneous loss of connection to the remaining transformer ("SGT2"). The consequence was the loss of all supplies from North Hyde 275kV substation, impacting thousands of customers, including Heathrow Airport.**

2.2 The resulting outage led to 71,655[1] domestic and commercial customers losing power, and the complete loss of supplies to part of Heathrow Airport's private internal electrical distribution network. Heathrow Airport Limited took the decision to close the airport due to the impact of the outage on some of its operationally critical systems.

2.3 Using forensic analysis from both National Grid Electricity Transmission and London Fire Brigade, this review has seen evidence that a catastrophic failure on one of SGT3's high voltage bushings caused a fire to ignite on the supergrid transformer. This was most likely caused by moisture entering the bushing causing a short circuit. The electricity likely then 'arced' (causing sparks) which combined with air and heat to ignite the oil, resulting in a fire.

2.4 An elevated moisture reading in one of SGT3's bushings had been detected in oil samples taken in July 2018. According to National Grid Electricity Transmission's relevant guidance, such readings indicate 'an imminent fault and that the bushing should be replaced'. While the reading was recorded in National Grid Electricity Transmission's online system, the mitigations appropriate to its severity were not actioned.

2.5 The controls in place were not effective and failed to identify subsequently that action had not been taken in relation to the elevated moisture reading. This includes an opportunity in 2022 when a decision was taken to defer basic maintenance on SGT3. The issue therefore went unaddressed.

2.6 The catastrophic failure and fire also caused damage to SGT1's high voltage bushings and its marshalling kiosk, which then caused its protection systems to operate 28 minutes after SGT3 tripped. This automatically switched SGT1 and SGT2 out of service, resulting in the loss of all supplies at North Hyde 275kV substation. It was not possible to keep either the North Hyde 275kV or 66kV substation sites operational because of the effects of heat and smoke from the fire, and the need to fight the fire safely.

2.7 While National Grid Electricity Transmission's current standards for fire controls at substation sites prioritise distance and physical barriers between oil-filled equipment, neither of these measures were in place at North Hyde 275kV substation site as it was built prior to the application of these standards.

2.8 Risks at the North Hyde site were managed by National Grid Electricity Transmission using multiple separate processes, meaning there was no single structured process to provide a cumulative assessment of the risk to the whole site.

1 Since the publication of the interim report, this review has been made aware of 4,736 customers of Independent Distribution Network Operators who were being supplied via North Hyde 66kV and 22kV substations and therefore also lost power during the incident. This is in addition to the 66,919 of SSEN Distribution's domestic and commercial customers referenced in the interim report.

2.9 The incident's effect on the wider electricity transmission system beyond North Hyde was limited, and the electricity system operated within the applicable standards. Incident management plans were followed by relevant parties and these operated largely as anticipated, although greater collaboration in the development and execution of these plans would have enabled a more coordinated response.

2.10 Considering the impact of the incident on Heathrow Airport, this review finds that the design and configuration of Heathrow Airport's private internal electrical distribution network meant that the loss of one of its three independent supply points would result in the loss of power to operationally critical systems, leading to a suspension of operations for a significant period. This situation was understood by Heathrow Airport Limited and there were plans in place to respond to such an event. These plans included the reconfiguration of the network, with an estimated timescale of 10-12 hours. NESO, National Grid Electricity Transmission and Scottish and Southern Electricity Networks Distribution ("SSEN Distribution") stated to this review that they were not previously aware of the potential impact to Heathrow Airport of the loss of a supply point.

2.11. The loss of supplies from a supply point was not assessed to be a likely scenario by Heathrow Airport Limited, due to its expectation of the resilience of the wider network. This meant that its internal electrical distribution network was not designed or configured to take advantage of having multiple supply points to provide quick recovery following such a loss and relied on manual switching.

2.12 As laid out in the Terms of Reference (see Appendix B), this review has also considered the wider learnings from the incident relating to energy resilience in CNI. Energy network operators are not currently aware whether customers connected to their networks are CNI, and there is currently no cross-sector requirement for CNI operators to ensure specifically the continuity of operations in response to power disruption. Further, CNI operators have no priority within the electricity legal or regulatory framework. Work is underway, led by government, to identify and analyse cross-sector CNI interdependencies.

2.13 Throughout the incident, relevant parties communicated effectively with the public and domestic customers, although some commercial customers have told this review that the communications they received were less coordinated. Customer restoration occurred within expected timeframes. The wider impact to the local area, including road, rail, and the environment, was relatively contained.

2.14 This review has sought to undertake root cause analysis of the incident, to understand both how it unfolded at an asset and site level, and the impact it had on domestic and commercial customers. This review makes a number of recommendations to reduce the likelihood and impact of a similar event in the future and serves as a starting point to make cross-sector improvements for the benefit of Great Britain and its energy resilience.

3. Recommendations

3.1 **This review has made the following recommendations. These recommendations will require close cooperation across industry, regulators, and lead government departments to ensure they are effectively implemented.**

Recommendations	Page
Asset management systems 1. Energy asset management processes and systems should include robust controls to ensure that identified issues are appropriately categorised and followed up on, including regular reviews of outstanding items. Particular attention should be paid to any area reliant on manual controls.	21
Maintenance actions 2. Asset owners should review the suite of mitigating actions deployed in the case of overdue maintenance to ensure they are comprehensive and capable of identifying issues likely to lead to asset failure with potential impacts on security of supply. Consideration should also be given to the use of the most up-to-date technology (e.g., continuous monitoring) to monitor the condition of critical assets.	22
Fire and asset risk assessments 3. Fire and asset risk assessments should: • Be in place for all energy facilities (including electricity and gas distribution, transmission, storage etc.) and explicitly cover all assets, and site level risk; • For site level assessments, cover the situation where there are multiple assets on a site, potentially controlled by different parties; • Explicitly include consideration of new or updated standards, even if there is no requirement to be retrospectively compliant; • Be updated (or explicitly cater for) when relevant equipment is unavailable or out of service; and • Incorporate input from the fire service, including on firefighting protocols.	27
Site accessibility for emergency services 4. Network asset owners and relevant emergency services should take the lessons learnt from the North Hyde incident to identify any required improvements to site and substation specific emergency management plans. This should include any learnings related to access requirements and where there is a single site with multiple assets under the control of different parties. These should be shared and incorporated into fire and asset risk assessments (as set out in recommendation 3) as appropriate.	29

Recommendations	Page
Visibility of total site risk 5. Overall risk assessments at an asset and site level should be undertaken (which would incorporate the fire and asset risk assessments as set out in recommendation 3). This should incorporate and mitigate for any cumulative or compounding risks (e.g., catastrophic failure of one asset having a wider impact on the continued operation of the site). This should also consider changes or lessons learnt relating to equipment, design, or construction standards which might reasonably be expected to change the outcome of the risk assessment. These site and asset risk assessments should explicitly factor in the implications for the wider energy network, security of supply and continuity of service for customers. Where there are potentially significant system, network or customer impacts, the risk assessment should be coordinated with NESO as appropriate.	31
Electricity Safety, Quality and Continuity Regulations (ESQCR) 6. Government and regulators should refresh guidance available on ESQCR, including clarifying roles and responsibilities.	33
Incident management protocols 7. For every CNI site, incident management protocols should explicitly include plans around loss or impairment of energy supplies. These protocols should include a mechanism to convene all relevant parties (including network companies, system operators, regulators, government etc. as appropriate).	35
Resilience of infrastructure with multiple supply points 8. Where a CNI or essential service site has multiple supply points connected to the energy system, explicit consideration should be given by the site operator to the level of resilience and operational continuity required, and how this can be achieved. This could include: i) Diversifying the configuration such that the loss of one supply point does not impact the entire CNI site. ii) The ability to switch load quickly between the supply points. For example, on the electricity system (e.g., via internal interconnectors, automatic/tele switching) and, where appropriate, the use of short duration uninterruptable power supply while switching takes place such that operations can be maintained.	39

Recommendations	Page
Energy resilience of CNI 9. CNI operators should be able to have transparent conversations, then work together with energy networks (transmission and/or distribution as appropriate) and system operators to review and establish a mutual understanding of the resilience and security of the energy supply arrangements to the CNI site.	42
10. CNI operators should develop a communication and operational protocol for addressing any planned and unplanned changes to resilience.	42
11. NESO and the government should work together to develop an appropriate holistic view of the CNI reliance on the energy system.	42
12. CNI operators, government and the relevant regulatory bodies should establish a more structured approach to energy resilience, for example via cross-sector partnerships and standards, including standards around continuity of operations under various scenarios (e.g., loss of an energy asset).	42

4. Electricity explainer

4.1 This section explains how transmission and distribution networks function to contextualise the North Hyde incident.

4.2 The transmission network is the electrical equivalent of the motorway network, transporting electricity over longer distances at higher voltages. The distribution networks are comparable to A and B roads, moving electricity around at lower voltages to where it is needed. In Great Britain, there are three phases or 'lanes' of the electricity network, named A, B and C.

4.3 At a national level, NESO, as the electricity system operator, makes sure that there is enough electricity to meet what is needed at any time of the day by balancing supply and demand. NESO is also responsible for directing configuration – how it all connects together – of the electricity transmission system.

4.4 Transmission and distribution networks use both overhead lines and underground cables, to create circuits and transport electricity. Substations are situated at multiple points on the network.

4.5 In a substation, a circuit delivers electricity at one voltage level, and in many places is reduced or 'stepped' down to a lower distribution voltage using a transformer. This is a large, specialist piece of equipment, generally with a tank containing an iron core with copper windings and filled with insulating oil. Electricity flows in from the incoming circuit via connectors through the three high voltage connections (or high voltage bushings) through the windings in the transformer, insulated and cooled by the oil which circulates through the transformer tank and its connected external radiator. Once the voltage is stepped down, it flows out through the three low voltage connections (low voltage bushings). This electrical process creates heat, so monitoring equipment is used to measure transformer winding temperatures and dissolved gas in the oil as indications of possible faults, alongside the protection equipment that monitors electrical flows. Enhanced monitoring techniques are increasingly being deployed which look out for evidence of issues such as partial discharge on a continuous basis.

4.6 Transformers contain a significant amount of oil, so they are mounted on a concrete pad within a transformer bund. This is a very large capacity pit that sits around and underneath the transformer itself to contain oil and water if necessary, minimising further impact to the site and its surrounding environment.

4.7 Marshalling kiosks bring together wiring for the protection and control system, which is used to monitor, control and protect assets, including transformers.

4.8 Supergrid transformers connect between the high-power transmission system and the lower power distribution system, transforming between different voltage levels (e.g., 400kV to 132kV, or 275kV to 66kV). Grid transformers then connect within the distribution system as the voltage levels further reduce to a standard domestic 230V connection.

4.9 Substations are also where resilience can be built into the network, installing extra equipment including transformers and switches (including circuit breakers) on an internal network or busbar. Busbars are electrical crossroads that allow the configuration to be switched around manually or automatically, swapping to standby equipment for maintenance or in case of faults.

5. The incident

5.1 This section describes the network configuration at the North Hyde substation site and Heathrow Airport, and how the incident unfolded.

North Hyde site

5.2 The North Hyde site is located east of Hayes in West London. There are four substations at the site: the 275kV (controlled by National Grid Electricity Transmission) and the 66kV, 22kV and 11kV (all operationally controlled by SSEN Distribution).

5.3 There are three supergrid transformers at North Hyde, located in the 275kV substation compound; SGT1, SGT2 and SGT3. These transformers are designed to reduce the voltage from 275kV to 66kV and are owned by National Grid Electricity Transmission.

5.4 SGT1 and SGT3 were commissioned in 1968 and are adjacent to one another. SGT2 was commissioned in 2010 and sits over 30 metres away from the other two transformers (see Figure 1).

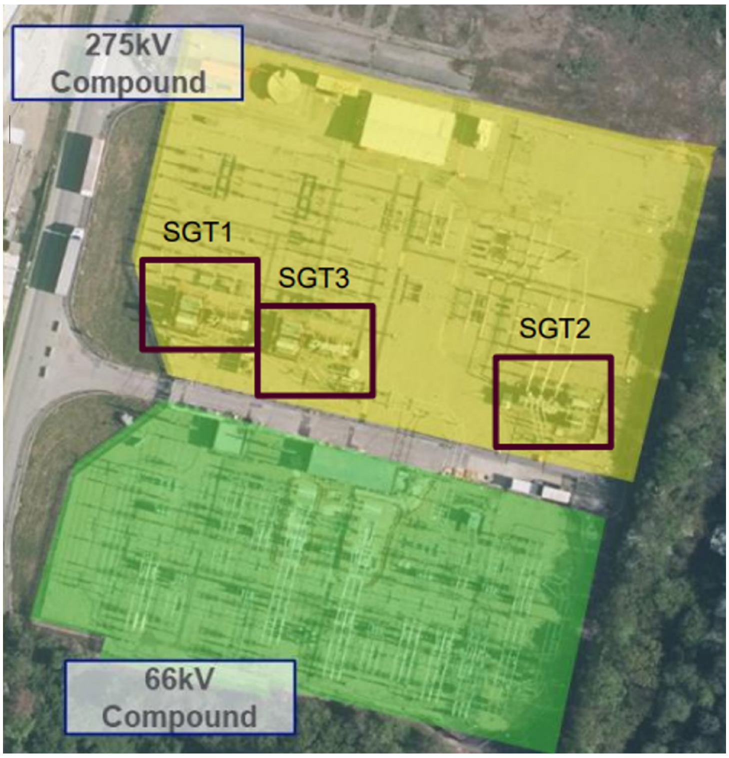

Figure 1: Image of North Hyde site

5.5 North Hyde 275kV substation is designed to operate with two transformers on-load and the third on 'hot standby' (i.e., energised and ready to switch in as needed). This is achieved using an autoclose scheme which operates automatically following the loss of either of the two in-service transformers, SGT1 or SGT3. The scheme is designed to switch SGT2 into service automatically if a problem is detected on either SGT1 or SGT3 that results in one of them having to be disconnected.

5.6 Figure 2 shows the approximate extent of the geographic area supplied by North Hyde. North Hyde 66kV substation feeds a number of lower voltage substations, also known as primary substations. These are 11kV substations and feed the coloured areas shown on the map.

5.7 Further information on the design and history of the North Hyde substation sites and the surrounding network is available in Appendix A.

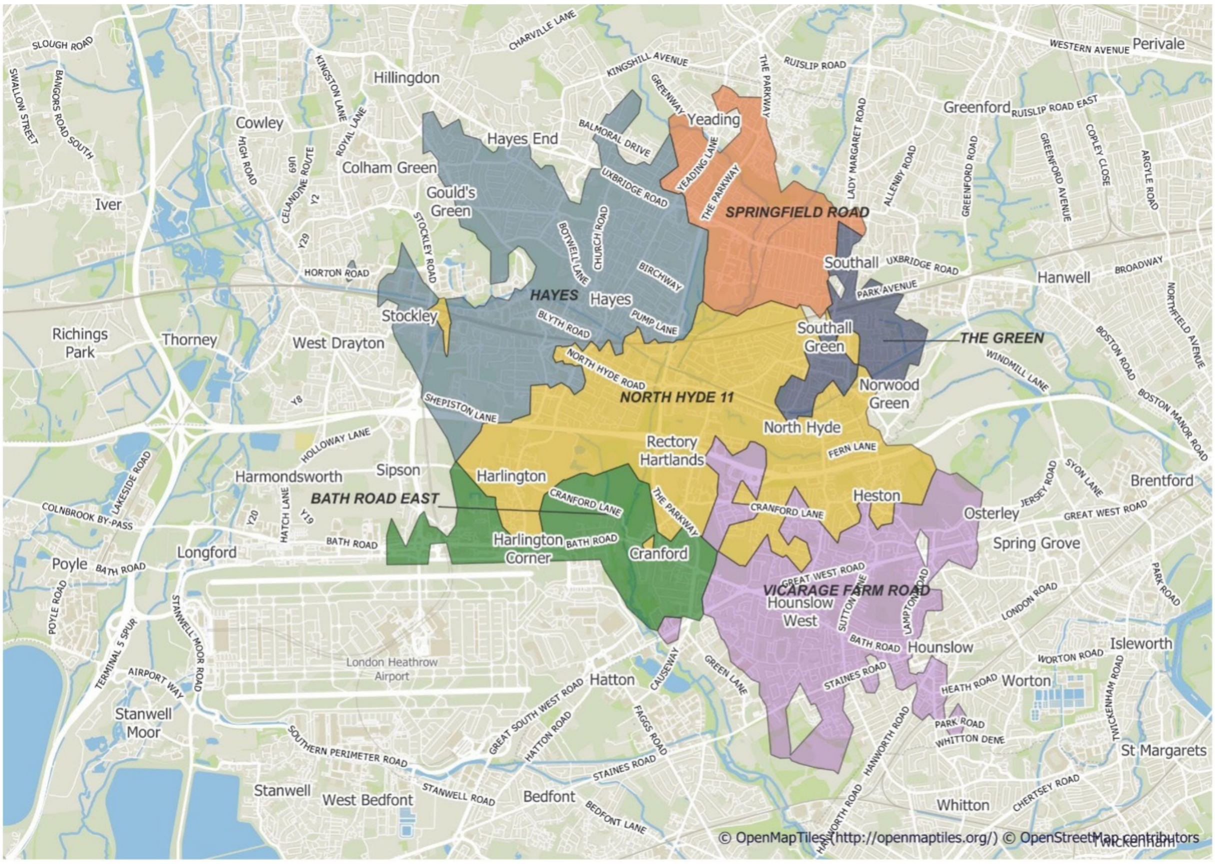

Figure 2: **North Hyde primary substation supply areas**

Heathrow Airport

5.8 Heathrow Airport is the largest airport in Europe and connects to over 230 destinations. It serves over 82 million passengers a year, and over 26% of the UK's exports by value.

5.9 Heathrow Airport's private internal electrical distribution network is designed to meet the airport's extensive energy needs. This network is separate to the distribution and transmission networks (owned and maintained by SSEN Distribution and National Grid Electricity Transmission respectively). The network, owned partly by Heathrow Airport Limited and partly by UK Power Network Services, includes all necessary infrastructure for electricity distribution, such as cables, ducts, and other equipment. The system includes a leased network, maintained and operated by UK Power Network Services, under contractual agreements with Heathrow Airport Limited.

5.10 Heathrow Airport's internal electrical distribution network is fed from three independent supply points, which each supply different areas and systems across the airport. One of these supply points (referred to in this report as "Heathrow Substation A") is usually fed from North Hyde 66kV substation. Heathrow Substation A in turn supplies some of the airport terminals, key airport operations and other facilities. There is a connection agreement between Heathrow Airport Limited and SSEN Distribution relating to this arrangement.

5.11 The three independent supply points are not normally connected to each other within Heathrow Airport's internal electrical distribution network. If they were connected, it would allow electrical power to continue to be supplied across Heathrow Airport's internal electrical distribution network if one supply point failed. However, this arrangement, running in 'parallel' to National Grid Electricity Transmission's and SSEN Distribution's networks, could result in damaging power flows through the Heathrow Airport internal electrical distribution network if a fault occurred on the transmission or distribution networks. Parallel operation can only be adopted after careful consideration, planning, and the installation of any necessary equipment. Heathrow Airport's internal electrical distribution network is not run in parallel operation on a continuous basis and the supply points are, therefore, not connected.

5.12 When necessary, for example in the event of a fault, it is possible to reconfigure supplies to be fed from a different point. This takes significant network switching.

5.13 The illustrative standard network configuration and supply to Heathrow Airport is shown in Figure 3. Further information on the configuration and operation of Heathrow Airport's internal electrical distribution network is available in Section 9.

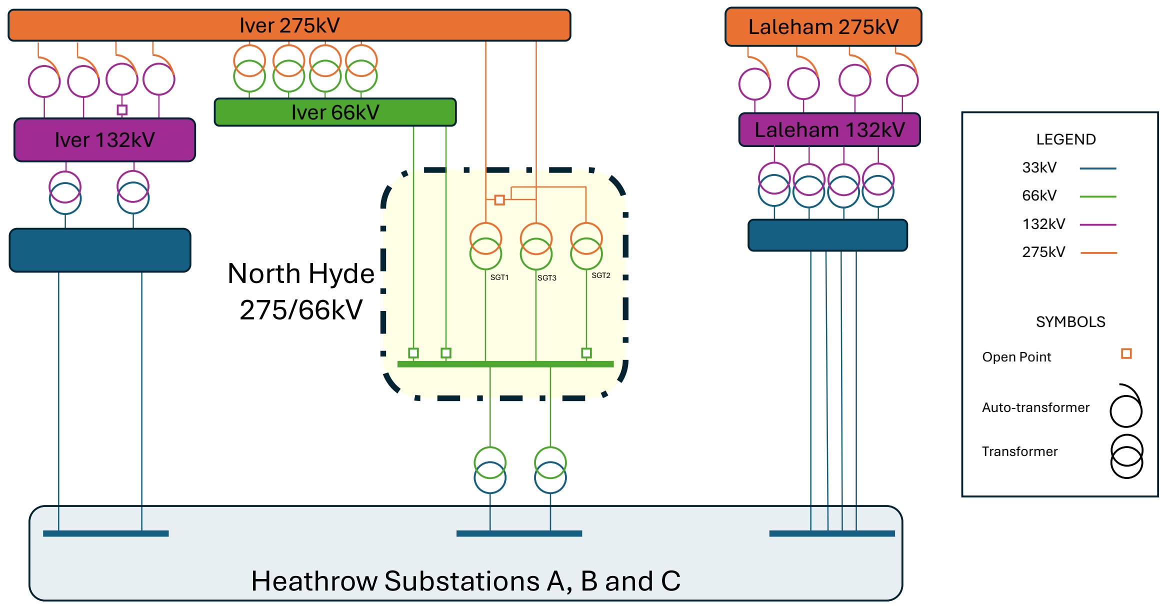

Figure 3: Illustrative standard network configuration and supply to Heathrow Airport

Power outage at North Hyde site

5.14 At 23:21 on Thursday 20 March, SGT3 at North Hyde 275kV substation and the circuit connecting it to the wider transmission system tripped. This left North Hyde 275kV substation being fed by a single transmission circuit. Multiple alarms associated with North Hyde's 275kV SGT3 circuit were received by NESO's and National Grid Electricity Transmission's control centres, indicating that SGT3 had been automatically disconnected from the network via switching triggered by its protection systems.

5.15 Immediately following the loss of SGT3, SGT2 - which had been running on hot standby - automatically switched into service and connected to the same 275kV circuit that fed SGT1. This operated as designed and restored a two-transformer supply into North Hyde 66kV substation, with no interruption of supply to customers.

5.16 At 23:49, 28 minutes after the loss of SGT3, SGT1's protection systems operated, automatically switching SGT1, and the circuit connecting it to the wider transmission system, out of service. As SGT2 was connected to the same circuit as SGT1, SGT2's direct connection to the wider transmission system was also lost.

5.17 At this point, as all three supergrid transformers could not be fed from the wider transmission system, there were no supplies to the North Hyde 66kV and 22kV substations.

5.18 This resulted in 66,919 of SSEN Distribution's domestic and commercial customers, and an additional 4,736 customers of Independent Distribution Network Operators who were being supplied via North Hyde 66kV and 22kV substations losing power, including a loss of supply to Heathrow Substation A. At 01:11 on Friday 21 March, Heathrow Airport Limited took the decision to close Heathrow Airport due to the disruption caused to operationally critical systems following the power outage.

Fire at North Hyde site

5.19 London Fire Brigade confirmed it received the first call about a fire at the North Hyde site at 23:22 on Thursday 20 March. The first fire appliance arrived at the site at 23:28, positioned outside the perimeter fence.

5.20 Over the following 30 minutes, London Fire Brigade requested nine additional fire appliances in order to tackle the fire safely. At 00:42 the Metropolitan Police Service declared a major incident.

5.21 In order to tackle the fire, London Fire Brigade worked with National Grid Electricity Transmission and SSEN Distribution to ensure power was isolated on the substation site, providing engineers with access, as required (see paragraphs 7.26 — 7.31).

5.22 The National Grid Electricity Transmission standby engineer had arrived at site by 23:50. By 06:00, permits were in place confirming electrical safety, which allowed London Fire Brigade to enter the site. This was in line with the National Fire Chief Council's National Operational Guidance for London Fire Brigade.

5.23 When required, and following risk assessments, London Fire Brigade worked with National Grid Electricity Transmission and SSEN Distribution to enable parts of the site to be re-energised whilst firefighting actions continued.

5.24 Power was returned on Friday 21 March to North Hyde 22kV substation at 00:39, North Hyde 66kV substation at 09:49, and on Saturday 22 March at 00:55 SGT2 at the North Hyde 275kV substation was energised and was put on-load at 02:22 (see paragraphs 8.12 – 8.15).

5.25 London Fire Brigade issued the stop message, confirming cessation of firefighting, at 17:13 on Wednesday 26 March, five days and 18 hours after it first arrived on site.

5.26 A high-level timeline of the incident is shown in Figure 4.

Thursday 20 March

- **23:21** SGT3 at North Hyde 275kV substation out of service following circuit trip
- **23:21** SGT2 automatically switches into service, restoring two-transformer supply to North Hyde
- **23:22** London Fire Brigade receives the first call about a fire at North Hyde substation
- **23:28** London Fire Brigade's first fire appliance arrives on site
- **23:49** SGT1 and its circuit, which was also feeding SGT2, trips meaning there are no supplies to North Hyde 66kV substation. 71,655 customers lose power, including Heathrow Substation A

Friday 21 March

- **00:47** SSEN Distribution has restored approximately 42,000 customers
- **01:11** Heathrow Airport Limited decides to close Heathrow Airport in response to disruption
- **06:25** Heathrow Airport Limited's control centre re-energises all primary substations by reconfiguring its private network
- **09:49** Busbars at North Hyde 66kV substation re-energised using SSEN Distribution's circuits from Iver 66kV substation
- **12:24** All SSEN Distribution's domestic customers restored
- **13:30** Heathrow Airport Limited begins safety checks to reopen for some repositioning and repatriation flights

Saturday 22 March

- **00:55** Re-energisation of North Hyde's SGT2
- **02:22** North Hyde's SGT2 put on load
- **19:22** Iver SGT4B switched and supplying load to two 66kV circuits from Iver to North Hyde

Figure 4: Timeline of the incident

Analysis and recommendations

Analysis and recommendations

The following sections set out this review's analysis and recommendations concerning the incident. In line with the primary root cause analysis methodology used for this review, it is split into:

- The asset (SGT3)
- The site (North Hyde)
- Electricity system
- Heathrow Airport
- Critical National Infrastructure
- Customers

6. The asset (SGT3)

6.1 This section presents this review's analysis and recommendations relating to the fire on SGT3, and National Grid Electricity Transmission's maintenance and controls relevant to the incident.

Key messages

- A catastrophic failure on one of SGT3's high voltage bushings caused a fire to ignite on SGT3. This was most likely caused by electrical arcing as a result of moisture ingress in the bushing.
- In July 2018, oil samples taken from SGT3's bushings indicated an elevated moisture reading on one of the high voltage bushings. The elevated moisture reading was recorded in National Grid Electricity Transmission's online system.
- While the reading was recorded, the mitigations appropriate to its severity, as set out in National Grid Electricity Transmission's relevant policy, were not actioned at the time.
- The controls in place were not effective and failed to identify subsequently that action had not been taken in relation to the elevated moisture reading. This review finds that there were other opportunities which, had they been pursued, could have caught the issue. Instead, the elevated moisture reading went unaddressed.

Fire on SGT3

6.2 At 23:21 on Thursday 20 March, SGT3 at North Hyde 275kV substation and the circuit connecting it to the wider transmission system tripped. Multiple alarms were received by NESO's and National Grid Electricity Transmission's control centres indicating that SGT3 had been automatically disconnected from the network by its protection systems. These protection systems operated as expected, isolating the power supply in approximately 110 milliseconds to prevent further electrical hazards.

6.3 A fault on the high voltage side of the supergrid transformer was detected and recorded. Shortly after the supergrid transformer was disconnected, National Grid Electricity Transmission received a high temperature warning for the winding of SGT3.

6.4 London Fire Brigade confirmed it received the first call about a fire at the North Hyde site at 23:22 (i.e., within a minute of SGT3 tripping).

Cause of the fire

6.5 The Metropolitan Police Service, supported by the Metropolitan Police Counter Terrorism Command, confirmed on Tuesday 25 March that it had 'found no evidence to suggest that the incident was suspicious in nature' and as a result closed its investigation into the fire.

6.6 Following the incident, National Grid Electricity Transmission commissioned Doble to conduct a forensic analysis to identify the root cause. Doble is a global specialist transformer condition assessment organisation, providing diagnostic and engineering services to the energy industry. Doble's forensic analysis indicated that the most likely cause was an electrical short circuit on the C-phase of the high voltage bushing on SGT3, resulting in the catastrophic failure of this bushing that led to a major fire on the transformer. The illustrative location of bushings within a supergrid transformer can be found in Figure 5.

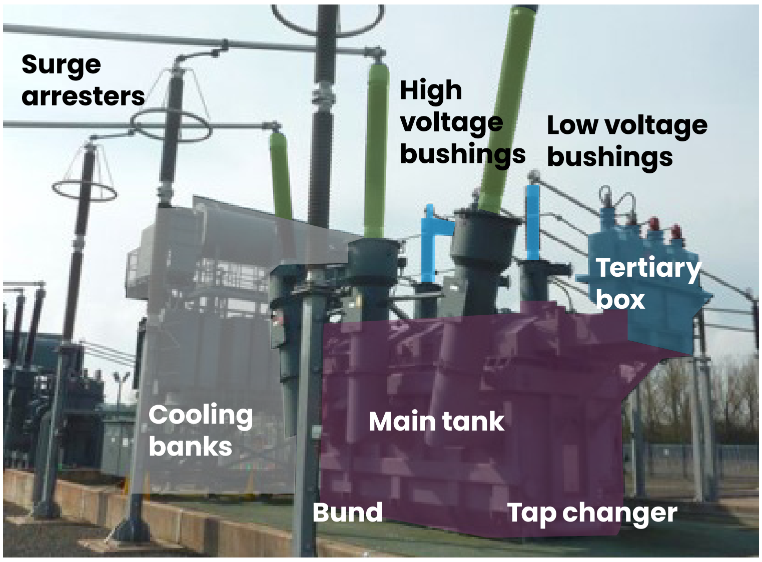

Figure 5: Illustrative location of bushings within a supergrid transformer

6.7 Doble's forensic analysis found that it was unlikely the failure started from the main tank or from the tap changer of SGT3, as there were no signs of a fault on these parts of the transformer. Equally, the oil sampling prior to the incident from the main tank and tap changer indicated no concerns.

6.8 After disassembly of the bushings, Doble found evidence of moisture ingress on the C-phase high voltage bushing that suffered the catastrophic failure. Such evidence of moisture ingress would not have been visible externally and therefore only became apparent after disassembly and forensic analysis post-incident by Doble.

6.9 The forensic analysis also found evidence of arcing erosions within the C-phase high voltage bushing. Arcing erosion is the damage caused by electrical arcs, which normally occurs due to electrical faults or contamination, including by moisture ingress. This damage can lead to the gradual degradation of parts of the bushings, and can result in reduced insulation resistance, potential short circuiting and ultimately, bushing failure. Phases A and B of the high voltage bushings did not show any evidence of arcing erosion, supporting the case that the fault was on the C-phase only and had arisen as a result of moisture ingress.

6.10 Due to the extensive fire damage of SGT3, it is unlikely that any greater certainty about the exact cause can be achieved.

6.11 London Fire Brigade also conducted its own internal investigation into the incident to understand the fire's initiation and spread. The London Fire Brigade's investigation findings mirror those made in Doble's forensic analysis relating to the fire's cause, although the investigation also notes there may be further underlying or contributory detail relevant to the cause of the fire outside of its scope.

Transformer susceptibility to fires

6.12 Fires can occur in supergrid transformers. However, across National Grid Electricity Transmission's network, there have been no faults involving fire on oil-filled wound plant in the last five years. A fire occurred on a supergrid transformer at Willesden substation (North West London) in 2015, during the early commissioning of the unit. This was related to an error with the commissioning process, rather than the unit itself. The last in-service supergrid transformer fire took place at Creyke Beck substation (Humberside) in 2013.

Elevated moisture readings

6.13 When a supergrid transformer is due maintenance, or is out of service, it can provide an opportunity to carry out inspections and take oil samples from the bushings, if it is appropriate to do so. These are not possible when the supergrid transformer is in operation.

6.14 In July 2018, oil samples were taken from SGT3's bushings during its basic maintenance. Readings from the C-phase of the high voltage bushing sample showed a category 1 moisture level in one bushing, the highest level in National Grid Electricity Transmission's technical guidance note 'The Management of Bushings', as was in place at the time in 2018. According to this guidance, readings at this level indicate 'an imminent fault and that the bushing should be replaced'.

6.15 National Grid Electricity Transmission's technical guidance note dictated that following elevated moisture samples, the asset should remain out of service until the bushing can be replaced, or mitigating actions put in place. While the reading was recorded, the mitigations appropriate to its severity, as set out in National Grid Electricity Transmission's relevant policy, were not actioned at the time.

6.16 The controls in place were not effective and failed to identify subsequently that action had not been taken in relation to the elevated moisture reading. Notwithstanding this, this review considers there were other potential opportunities which could have caught the issue, had they been pursued. For example:

- A new internal procedure was issued by National Grid Electricity Transmission in December 2020, providing clearer guidance on the process and roles and responsibilities related to oil sampling. However, this procedure did not require a retrospective check of existing records. A review of category 1 readings that indicated an imminent fault could have prompted a further check of the associated mitigations for those readings, which may have revealed that no actions were in place to manage the risk to SGT3.
- Under National Grid Electricity Transmission's current maintenance policy, basic maintenance was due on SGT3 in March 2024 and major maintenance due in April 2028. While there were several attempts to schedule the basic maintenance, it did not occur (see paragraph 6.25). Mitigations for the deferred maintenance on SGT3 were put in place in line with the policy (see paragraphs 6.25 – 6.26 below). National Grid Electricity Transmission has explained to this review that oil sampling of the bushings is not included as part of basic maintenance and is planned separately, although it may align with other scheduled maintenance activities as appropriate. This review considers that, had the basic maintenance been conducted, National Grid Electricity Transmission could have utilised the opportunity of the transformer being out of service to conduct oil sampling, which may again have brought attention to the elevated moisture reading on the C-phase bushing.
- There are advanced online continuous condition monitoring solutions which may have enabled detection of partial discharge or arcing prior to the incident. These are deployed in certain circumstances on the transmission system already. In response to National Grid Electricity Transmission's funding request in 2018 (RIIO-2 T2 submission), Ofgem allowed National Grid Electricity Transmission's request for £18.65 million, plus indirect costs, to invest in advanced condition monitoring technologies, outside of normal network operating costs funding. The criteria for prioritising this technology on certain sites over others are based on an assessment of factors such as asset population, asset age and historical performance data. This technology was not in place in North Hyde, where National Grid Electricity Transmission had made the decision that it did not meet these criteria.

6.17 National Grid Electricity Transmission explained that, following the incident, it has initiated an end-to-end review of its oil sampling process, with a view to ensuring that it is robust. In addition, National Grid Electricity Transmission has indicated that it is also undertaking a review and assurance exercise of all recorded oil samples to ensure all appropriate actions have been taken where required.

Recommendation: Asset management systems

1. Energy asset management processes and systems should include robust controls to ensure that identified issues are appropriately categorised and followed up on, including regular reviews of outstanding items. Particular attention should be paid to any area reliant on manual controls.

Asset life, inspection, and maintenance

Asset life

6.18 To determine if an asset is approaching its end of life and due for replacement, National Grid Electricity Transmission apply an End of Life (EOL) Modifier score, based on a yearly assessment. A newly commissioned supergrid transformer in perfect operational condition would be expected to have an EOL score of 0, whereas a supergrid transformer that has reached the end of its operational life would be expected to have an EOL score at or approaching 100.

6.19 Prior to the incident, National Grid Electricity Transmission had given SGT3 an EOL score of 12.7 out of 100. According to National Grid Electricity Transmission, this would indicate that there was no driver for replacement or removal from service of this transformer. Transformer bushings are not factored into EOL calculations, as these are replaceable components and therefore would not affect the EOL score for SGT3.

Inspection and maintenance

6.20 Maintenance policies for transformers and substations are the responsibility of the asset owner and are not dictated by a specific set of regulations, although they are underpinned by general legal and regulatory obligations. Alongside these legal and regulatory obligations, Ofgem's Network Asset Risk Metric (NARM) enables a regulatory output to be established that measures the effectiveness of a licensee's asset replacement and refurbishment activities. NARM includes a methodology for calculating network risk, to a set of reporting metrics, and a funding mechanism designed to ensure network companies are held accountable for their asset management decisions.

6.21 In common with other network equipment, supergrid transformers are subject to regular maintenance and inspection. National Grid Electricity Transmission follows condition-based and time-based policies for supergrid transformer maintenance, where maintenance occurs at defined intervals. According to its current policy, which came into effect in 2023, basic maintenance on a supergrid transformer should occur within five years and major maintenance within fifteen years of the previous major maintenance.

6.22 Prior to 2023, the previous version of the policy stated that basic maintenance should occur within four years and major maintenance within eleven years of the previous maintenance.

6.23 In instances where it has not been possible to complete any maintenance in time or it is overdue, National Grid Electricity Transmission's current policy states that a deferred maintenance risk assessment should be undertaken. Following this, mitigating actions should be put in place to guarantee the safety of personnel on site (if the existing control measures are not sufficient to do so).

6.24 National Grid Electricity Transmission's records show that the last basic maintenance on SGT3 was completed on 28 July 2018, while the last major maintenance was completed on 26 June 2012. When the policy changed in 2023, the due date for basic maintenance on SGT3 became 31 March 2024 and 2 April 2028 for major maintenance. Under the pre-2023 version of the policy the next basic maintenance would have been due by the end of the financial year in 2022/23 and the next major maintenance by the end of the financial year 2023/24.

6.25 Evidence provided to the review revealed that multiple attempts were made to schedule basic maintenance on SGT3, none of which went ahead.

- A planned outage to enable maintenance to take place on SGT3 was scheduled for 4 October 2021. It was delayed due to National Grid Electricity Transmission's reprioritisation for other higher risk works.
- A further outage to enable the maintenance was scheduled for 10 October 2022. Shortly before the outage window, an issue on North Hyde SGT1 meant the planned maintenance could not go ahead. National Grid Electricity Transmission cited it was unable to replan the maintenance within the next outage planning year, which runs from April to March.
- From December 2022 onwards, a number of mitigating actions on SGT3 were implemented, as it was known that basic maintenance would be overdue by March 2023 (under the pre-2023, and then in force, policy). These included requiring that a Radio Frequency Interference condition monitoring survey and a thermovision inspection should be carried out every three months. Whilst these actions would not have identified moisture in the C-phase bushing, they may have identified issues caused by moisture ingress.
- Maintenance was replanned for 2 September 2024. This did not occur as an equipment defect at the nearby Iver 275kV substation meant that North Hyde 275kV was needed to secure the system and could not be taken out of service.
- The next planned outage to enable maintenance was scheduled for 19 May 2025. This was moved back until 17 November 2025 to optimise National Grid Electricity Transmission's overall resource availability.

6.26 Evidence has been provided by National Grid Electricity Transmission to show that the Radio Frequency Interference condition monitoring surveys and thermovision inspections required as a result of the deferred maintenance were carried out as planned every three months. The last surveys were completed in December 2024 with no concerns identified. The next surveys were due to be conducted on 23 March 2025.

6.27 National Grid Electricity Transmission's maintenance policy targets 85% of assets being within their normal maintenance cycle, with no more than 15% outside this cycle and in a deferred risk assessment process that assesses and applies any required mitigating actions to manage risks. As of May 2025, 697 of 805 transformers (87%) were within the maintenance frequency target. The remaining 108 were within a deferred risk assessment process.

Recommendation: Maintenance actions

2. Asset owners should review the suite of mitigating actions deployed in the case of overdue maintenance to ensure they are comprehensive and capable of identifying issues likely to lead to asset failure with potential impacts on security of supply. Consideration should also be given to the use of the most up-to-date technology (e.g., continuous monitoring) to monitor the condition of critical assets.

7. The site (North Hyde)

7.1 This section presents this review's analysis and recommendations relating to the impact of the incident on the North Hyde site, including on SGT1 and the wider site, the access to North Hyde for emergency services, and National Grid Electricity Transmission's site fire controls and risk management relevant to the incident.

Key messages

- The catastrophic failure of the high voltage bushing and subsequent fire on SGT3 resulted in damage to one of SGT1's high voltage bushings and marshalling kiosk. Its protection systems operated 28 minutes after SGT3 tripped. This automatically switched SGT1 and SGT2 out of service; SGT2 was connected to the same high voltage circuit supplying SGT1. This resulted in the loss of all supplies at North Hyde 275kV and 66kV substations. As a result, all customers fed from North Hyde were disconnected from 23:49.
- It was not possible to keep the North Hyde 275kV or 66kV substation sites operational because of the effects of heat and smoke from the fire on SGT3, and the need to fight the fire safely.
- National Grid Electricity Transmission's current standards for site fire controls prioritise distance and physical barriers between oil-filled assets. However, these were not in place for SGT1 and SGT3 at North Hyde as these assets were commissioned in 1968 prior to the application of these standards.
- Fire and asset related risks at the North Hyde site were being managed by National Grid Electricity Transmission using multiple separate processes. This meant that there was no single structured process to provide a cumulative assessment of the risk to the entire site and its wider system and customer impacts.

Spread and impact of the fire

Figure 6: Aerial photo of SGT3 taken by London Fire Brigade drone, Friday 21 March 2025 02:22:50

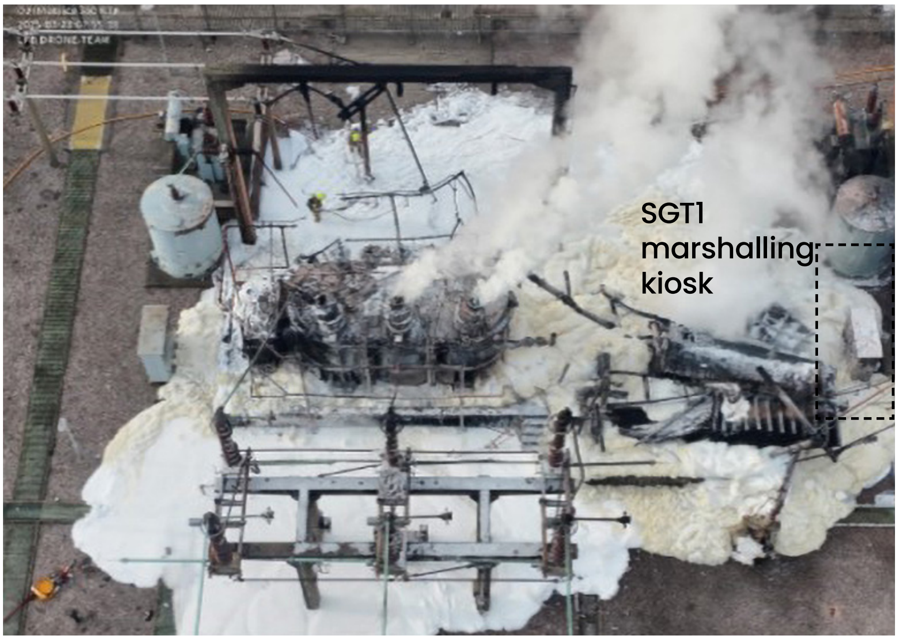

Figure 7: Aerial photo of SGT3 taken by London Fire Brigade drone, Friday 21 March 2025 07:55:38

7.2 While the fire occurred on SGT3, fire, heat and smoke impacted the wider North Hyde site. In particular, SGT1's marshalling kiosk was affected, and its wiring sustained significant damage. The marshalling kiosk for SGT1, as shown in Figures 6 and 7, was located to the west of SGT3, in between SGT3's cooling system and SGT1.

7.3 The wind direction at the time of the incident was instrumental in causing the damage to SGT1's marshalling kiosk due to the fire and heat directed towards it. In contrast, the marshalling kiosk for SGT3, which was upwind of the fire, remained largely undamaged. The damage to the marshalling kiosk for SGT1 and the wiring inside it may have triggered SGT1's protection systems to operate, automatically switching SGT1 and the circuit connecting it to the wider transmission system out of service.

7.4 National Grid Electricity Transmission's internal review has indicated from preliminary findings that the catastrophic failure of SGT3's C-phase high voltage bushing ejected pieces of porcelain insulator at high velocity, causing collateral damage to the A-phase high voltage bushing of SGT1. National Grid Electricity Transmission states that it is highly likely, although not confirmed, that a flashover on the A-phase high voltage bushing on SGT1 caused by a combination of heat, oil fire smoke and physical damage might also have triggered SGT1's protection system to operate.

7.5 It is not possible to confirm which specific protection operated and tripped SGT1. There are no available records from SGT1's overall protection for the time of the trip because the damage to the marshalling kiosk for SGT1 and the wiring inside it led to multiple event records being triggered, overwriting data from the time of SGT1's trip. Therefore, the damage to SGT1's marshalling kiosk due to fire and heat and a 'highly likely' flashover on the A-phase high voltage bushing on SGT1 remain the two possible causes of SGT1's trip.

7.6 Although SGT2 was not damaged by the fire, it de-energised at the same time as SGT1 because, due to the site's design, it was connected via the same circuit to the wider transmission system. At this point, all supplies were lost from the North Hyde 275kV, 66kV, 22kV, and 11kV substation sites.

7.7 The fire impacted the adjacent outdoor 66kV substation site, owned by National Grid Electricity Transmission and operated by SSEN Distribution. The severity of the safety risk posed to personnel and equipment from smoke and carbon deposits on the busbars and switchgear could not be determined initially. The smoke further reduced nighttime visibility on and around both the 275kV site and the adjacent 66kV site.

7.8 These risks led to SSEN Distribution's field staff assessing at 00:34 on Friday 21 March that, although the nearby indoor North Hyde 22kV substation could be re-energised, re-energisation of the 66kV substation was not deemed safe due to smoke obscuring the site and the potential flashover risk. SSEN Distribution was only able to re-energise the 66kV substation site at 09:40 once access had been given by London Fire Brigade.

7.9 In its fire investigation report, London Fire Brigade states that debris from SGT3's bushing was found on the ground around the substation between the service road and the supergrid transformers. This review has not seen any evidence to suggest that debris spread outside the confines of the substation perimeter.

Fire controls

7.10 North Hyde 275kV substation was built in 1968, by the Central Electricity Generating Board, with limited physical distance and no fire barrier in place between SGT1 and SGT3.

7.11 In the mid-1990s, National Grid Electricity Transmission developed a new limitation of fire risk technical standard for substations which included a hierarchy of fire controls.[2] According to this technical standard there were three methods to manage fire risk from oil-filled equipment. In order of preference and effectiveness these were:

a. Sufficient physical separation between the fire hazard and elements at risk.

b. Installation of fire barriers between the fire hazard and the elements at risk.

c. Protection of the fire hazard by a fire deluge system.

7.12 In the late 1990s, National Grid Electricity Transmission initiated a project to review fire risks for close proximity assets. This resulted in the fire suppression system being added to SGT1 and SGT3 at North Hyde 275kV substation in 2002. National Grid Electricity Transmission stated that due to how SGT1 and SGT3 had originally been placed, there was insufficient space between the assets to install fire barriers (which would have been preferable according to the hierarchy), hence the installation of a fire suppression system.

7.13 In 2010, National Grid Electricity Transmission built a third transformer connecting the 275kV and 66kV substations. The supergrid transformers were re-numbered to incorporate the new transformer, known as SGT2. SGT2 was built approximately 30m distance away from SGT1 and SGT3, with this physical separation providing a fire damage zone around SGT2 that did not affect existing site equipment. Physical separation was assessed as the primary control for the fire risk assessment under the revised technical standard, such that a barrier and/or fire suppression system were not required for SGT2.

7.14 In 2024, the limitation of fire risk technical standard was updated again, this time stating that fire suppression systems should be adopted only by exception as an appropriate fire control for new sites.[3] This change in technical specifications in 2024 was not applied retrospectively to older installations and therefore did not prompt a revised risk assessment of sites where the primary fire control was a suppression system.

7.15 According to National Grid Electricity Transmission's policies applicable for the North Hyde 275kV substation site, given that neither separation nor a fire barrier were possible between SGT1 and SGT3 in their current positions, it is reasonable to conclude that a fire suppression system was the only fire control that could have been in place for these assets.

Fire controls at North Hyde 275kV substation

7.16 The fire suppression system installed at North Hyde 275kV substation was a high velocity system, intended to extinguish a high temperature oil fire.

7.17 A National Grid Electricity Transmission review in 2022 indicated that the fire suppression system on SGT1 and SGT3 at North Hyde 275kV substation was inoperable. A further fire risk assessment report conducted in July 2024 indicated that the fire suppression system at North Hyde substation was still out of service.

7.18 The July 2024 fire risk assessment stated that if a fire started on any of the three supergrid transformers, 'it would not be suitably suppressed'. As a result, a high priority action was created on the pump of the water mist system to be appropriately serviced and maintained. That action remained outstanding at the time of the incident, in March 2025. National Grid Electricity Transmission stated that it was planning a combination of replacements and refurbishments of the fire suppression system by October 2025.

2 National Grid Technical Specification, Limitation of Fire Risk in Substations, TS 3.01.003, Issue 2, January 2013
3 Generic Electricity Substation Design Manual For Civil, Structural And Building Engineering Section No : 06 Limitation Of Fire Risk At Electricity Substations, TS_2.10.06, Issue 2, August 2024

Fire controls during the incident

7.19 National Grid Electricity Transmission assessed that, due to the nature of the catastrophic failure in this incident, the fire suppression system at North Hyde 275kV substation would not have prevented the fire on SGT3 from occurring. National Grid Electricity Transmission also noted that fire suppression or deluge systems are the least effective method of limiting the fire hazard that supergrid transformers represent. It stated that a deluge system may be successful at quenching minor fires that occur on bushings and tap changers. Should a catastrophic failure occur, it is possible that a deluge system could extinguish the fire, but it is more likely, in an explosive failure, that the deluge system would not be effective and/or the deluge system itself could be damaged and would not work to full capacity.

7.20 Following the incident, London Fire Brigade observed that the fire suppression system was most likely damaged during the initial electrical failure and initiation of the fire.

7.21 This review has been unable to establish what effect the fire suppression system would have had in suppressing the fire if it had been in service.

Fire risk assessment

7.22 National Grid Electricity Transmission uses a third-party contractor to conduct its fire risk assessments. The contractor carries out site fire risk assessments and makes recommendations in line with relevant legislation and British Standards, including The Regulatory Reform (Fire Safety) Order 2005, British Standard 5306 'Fire extinguishing installations and equipment on premises', and British Standard 476 'Fire Tests'.

7.23 This review finds that the fire risk assessment carried out in relation to the North Hyde 275kV substation did not include a specific site-level assessment of the risk to security of supply as a result of fire from oil-filled assets on a substation compound. It also did not include a specific risk assessment of the adequacy of fire controls in preventing the spread of fire between the oil-filled assets across the site.

7.24 Following the incident, National Grid Electricity Transmission has commenced work to review and develop the controls in place for fires at its operational sites. This will look to ensure the safety and effectiveness of its fire risk management and response. This work will review fire risk assessment processes for all operational sites and assets incorporating learnings from the incident and will review controls on sites with close proximity oil-filled assets.

Recommendation: Fire and asset risk assessments

3. Fire and asset risk assessments should:

- Be in place for all energy facilities (including electricity and gas distribution, transmission, storage etc.) and explicitly cover all assets, and site level risk;
- For site level assessments, cover the situation where there are multiple assets on a site, potentially controlled by different parties;
- Explicitly include consideration of new or updated standards, even if there is no requirement to be retrospectively compliant;
- Be updated (or explicitly cater for) when relevant equipment is unavailable or out of service; and
- Incorporate input from the fire service, including on firefighting protocols.

Access to site for emergency services

7.25 The four principal parties who attended the substation site at North Hyde immediately following the fire were National Grid Electricity Transmission, SSEN Distribution, the Metropolitan Police Service, and London Fire Brigade. Overall, evidence seen by this review suggests that parties worked collaboratively on the site to facilitate access for safety switching, which then allowed London Fire Brigade to start tackling the fire.

Sequence of events

7.26 London Fire Brigade received an initial call about the fire at North Hyde at 23:22 on Thursday 20 March. The first fire appliance arrived at the site at 23:28, with six additional pumps requested at 23:35, increasing to a request for ten by 23:54. London Fire Brigade told this review that it began tackling the fire at 05:36 on Friday 21 March, after it received confirmation in the form of permits to work from National Grid Electricity Transmission that the site had been made safe for London Fire Brigade to enter. Work before that point focused on preparation for firefighting such as laying out hoses, rather than containing the fire from the perimeter as stated in the interim report.

7.27 Permits to work are issued by electricity network operators to ensure the system is safe for fire crews to enter sites and begin firefighting. The permits provide written confirmation that the power to the site is isolated, and are completed by a Senior Authorised Person, who works with the relevant control centre and individuals on site to ensure that equipment is isolated and earthed, as necessary. The permit outlines the scope of the work, safety precautions, and any operational restrictions to ensure the safety of personnel on site. It can take several hours to complete the work necessary to ensure a substation site is safe for entry.

7.28 To establish a safe area of work for London Fire Brigade to fight the fire, National Grid Electricity Transmission needed to carry out safety switching to isolate equipment. On-site assessments indicated a more complicated approach was needed due to the fire. This required alternative and additional points of isolation and earthing to be made at Iver and North Hyde 275kV substations. Points of isolation and earthing were also required at North Hyde 66kV substation on the 66kV circuits of SGT3, SGT1 and SGT2. These switching activities included the manual application of portable, primary earths at multiple circuit locations and the writing of a complex permit for work on multiple circuits across three locations.

7.29 Logs from National Grid Electricity Transmission's control centre show that the switching activities were undertaken between 01:35 and 05:36 on Friday 21 March. This review considers that this was a reasonable timeframe given the complexity and challenging conditions.

7.30 National Grid Electricity Transmission has told this review that it hosted London Fire Brigade at a neighbouring site (Iver), during the financial year 2023/24. National Grid Electricity Transmission stated it discussed hazards such as oil-filled transformers at West London sites (including North Hyde) and its safety rules, including the instruction to await a Senior Authorised Person to arrive on site before London Fire Brigade should enter the compound or begin any firefighting. Evidence provided to this review by London Fire Brigade suggests this instruction was followed on the night of the incident.

7.31 London Fire Brigade noted that on arrival to North Hyde during the incident, it did not receive a 'Tab 4' package from National Grid Electricity Transmission. A Tab 4 is intended to provide site-specific information and risks to the fire service in the event of a fire to inform firefighting and is required as part of the emergency service arrangements under Article 13(3) of the Regulatory Reform (Fire Safety) Order, 2005. However, London Fire Brigade judges that receipt of a Tab 4 would have been unlikely to impact its approach to the fire, as engineers from National Grid Electricity Transmission and SSEN Distribution would still be required to attend the site to ensure its safety prior to firefighting.

Recommendation: Site accessibility for emergency services

4. Network asset owners and relevant emergency services should take the lessons learnt from the North Hyde incident to identify any required improvements to site and substation specific emergency management plans.

   This should include any learnings related to access requirements and where there is a single site with multiple assets under the control of different parties. These should be shared and incorporated into fire and asset risk assessments (as set out in recommendation 3) as appropriate.

SGT1 and SGT2 asset maintenance

7.32 The asset maintenance history of SGT3 is set out in Section 5.

7.33 Regarding maintenance of the wider 275kV substation site, the last basic maintenance on SGT1 was completed on 24 May 2021, while the last major maintenance was completed on 6 July 2011. Under the pre-2023 version of the policy, which was applicable when both sets of maintenance were undertaken, the next major maintenance was originally due in financial year 2022/23 and the next basic maintenance was due in 2025/26. Following the policy change, both basic and major maintenance were due in 2026/27. As major maintenance had not taken place by the start of winter 2022, National Grid Electricity Transmission began implementing mitigating actions on 13 October 2022. These were the same mitigating actions as on SGT3 (i.e., thermovision and a Radio Frequency Interference condition monitoring survey, scheduled to take place every three months). Actions remained in place even though under the current post-2023 maintenance schedules, no maintenance on SGT1 was overdue.

7.34 SGT2 has no active deferred maintenance risk assessment in place, therefore no mitigating actions were required.

Total site risk management

7.35 National Grid Electricity Transmission operates a corporate level risk management framework of 'principal' (parent) and 'subset' (child). Principal risks, such as public safety or loss of supply, are given priority focus. National Grid Electricity Transmission seeks to manage these risks both before and after installation and through continuous improvements to processes and policies.

7.36 National Grid Electricity Transmission has a principal risk for loss of supply which describes the risk that an asset (or assets) fails on the transmission system resulting in the loss of supply regardless of cause. This principal risk then cascades down to the asset management system, which looks at asset risks. National Grid Electricity Transmission also has a listed asset risk for fires at operational sites which result in damage to an asset/assets and loss of supply.

7.37 This review has also seen evidence of:

- The risk management processes and procedures National Grid Electricity Transmission has in place prior to an asset being in situ, including:
  - How National Grid Electricity Transmission manages designs on projects through the investment process to ensure the assets are fit for purpose and they are assessed for placement in an existing site;
  - Policies relating to maintenance, maintenance deferral (and associated risk mitigations); and
  - The production of asset level learning notes (Operational, Engineering & Safety Bulletins).

- Policies relating to maintenance, maintenance deferral (and associated risk mitigations), and the production of asset level learning notes (Operational, Engineering & Safety Bulletins).
- The three line assurance process National Grid Electricity Transmission has in place consisting of first line (e.g., site level inspections), second line (National Grid Electricity Transmission risk team who test controls), and third line (Corporate Audit and ISO accreditations).
- A formal process to translate assurance results into remediation actions.
- A formal process to escalate risk.

7.38 However, National Grid Electricity Transmission has confirmed that, under the above outlined risk management framework:

- National Grid Electricity Transmission does not produce a specific, site-level risk assessment which considers aggregated or compounded risks for individual sites. This review notes that there is currently no specific regulatory requirement for National Grid Electricity Transmission to do so. National Grid Electricity Transmission instead incorporates substation risks in its corporate risk register via the loss of supply and fire damage risks described above. This meant that there was not a site-specific risk assessment for North Hyde which considered the cumulative risk profile of assets, maintenance status, fire control availability or the sensitivity of the load fed by the site.
- Specific risk mitigation decisions on a site, for example the deferral of maintenance, are not systematically influenced by the presence of other existing risk mitigations on the site (though do consider wider outage requirements on the network). In the case of North Hyde 275kV substation, this meant that there was no process in place to consider the risk to availability of the whole site from the combination of the unavailability of the fire suppression system and the deferral of maintenance to the supergrid transformers.

7.39 Following the incident, National Grid Electricity Transmission has commenced a project to evaluate the effectiveness of its risk assessment and risk management framework in order to recommend critical control improvements and implement changes where required. This is aimed at developing an overall risk profile at a site level and connected assets, which considers aggregated risks. National Grid Electricity Transmission has stated that these activities will be conducted by independent experts on risk management, starting at a pilot site.

Recommendation: Visibility of total site risk

5. Overall risk assessments at an asset and site level should be undertaken (which would incorporate the fire and asset risk assessments as set out in recommendation 3). This should incorporate and mitigate any cumulative or compounding risks (e.g., catastrophic failure of one asset having a wider impact on the continued operation of the site). This should also consider changes or lessons learnt relating to equipment, design, or construction standards which might reasonably be expected to change the outcome of the risk assessment.

   These site and asset risk assessments should explicitly factor in the implications for the wider energy network, security of supply, and continuity of service for customers.

   Where there are potentially significant system, network or customer impacts, the risk assessment should be coordinated with NESO as appropriate.

Restoration of assets at North Hyde 275kV substation

7.40 Since the incident, National Grid Electricity Transmission has been proactively working to restore the North Hyde 275kV substation to a three-transformer configuration. National Grid Electricity Transmission's current plan is to bring SGT1 back into service in summer 2025 and to introduce a new supergrid transformer replacing SGT3 by early 2026. However, these dates are subject to change and depend on the successful commissioning of individual pieces of equipment. The new supergrid transformer is planned to be installed in a different location within the 275kV substation site. This will enable physical distance between the three supergrid transformers on the site, which is the preferred fire risk mitigation in line with current technical specifications.

8. Electricity system

8.1 **This section presents this review's analysis and recommendations relating to the impact of the incident on the wider electricity system, the use of incident management plans and the convening of relevant parties.**

Key messages

- Whilst the incident had a significant local impact, the effect on the wider electricity transmission system beyond North Hyde was limited.
- The electricity system operated within the applicable standards (specifically, the Security and Quality of Supply Standard and Engineering Recommendation P2).
- Relevant parties initiated and followed their own incident management plans and these operated largely as anticipated. However, greater collaboration in the development and execution of these plans may have enabled a more coordinated response.
- The incident was reported under the Electricity Safety, Quality and Continuity Regulations 2002 (ESQCR) by National Grid Electricity Transmission. Whilst the Health and Safety Executive has informed this review that it regulates 'safety' aspects of the ESQCR, it has not been possible for this review to identify fully the role or identity of other regulatory bodies responsible for assessing ESQCR compliance in relation to the fire at North Hyde substation, or wider obligations contained in ESQCR.

System impact

8.2 Despite the incident having a significant localised impact, the effect on the wider electricity transmission system was minimal. The outage resulted in a loss of 96MVA of national transmission demand. System conditions were stable at the time of the first fault (23:21), with an overall demand of 23,540MW. As a result of the incident, there were no breaches outside operational limits on frequency or voltage, nor were there any other associated impacts on the wider transmission system.

Applicable electricity system standards

8.3 The National Electricity Transmission System in England predominantly operates at 400kV and 275kV. The planning, development and operation of the transmission system is required to be in accordance with the Security and Quality of Supply Standard (SQSS) under the transmission licences and the Electricity System Operator licence. The SQSS determines the minimum level of security of supply provided to various levels of demand connections.

8.4 The SQSS specifies a level of security of supply by setting out the 'secured events' for which unacceptable conditions should not arise. When assessing demand connection capacity, this means that demand connections are planned and operated to stay within security criteria for the secured events of a fault outage (N-1) and planned outage followed by a fault outage (N-1-1). It is recognised that unsecured events may occur, and these could be more onerous than secured events. When unsecured events occur, their impact may lead to the operation of the system outside of normal parameters.

8.5 National Grid Electricity Transmission has confirmed to this review that it discharged its responsibility regarding SQSS compliance for the transmission system supplying North Hyde 275kV substation. This review supports this statement.

8.6 Engineering Recommendation P2, published by the Energy Networks Association, has a similar function to the SQSS for electricity distribution networks. The distribution networks in England operate at 132kV and below. P2 stipulates minimum demand to be restored within defined periods of time in different outage scenarios. Standard Condition 24 of the Electricity Distribution Licence requires licensees to plan their system with a standard not less than P2.

8.7 SSEN Distribution has confirmed to this review that the design of its network met the P2 standard and supplies were restored within the timelines required. This review supports this statement.

8.8 The Electricity Safety, Quality and Continuity Regulations 2002 (ESQCR) is a set of regulations aimed at protecting consumers from danger relating to electrical networks and equipment, as well as outlining electricity quality and supply continuity requirements. Duty holders have specific regulatory requirements under ESQCR in relation to safety and fire management at electricity substations, and as a result of incidents causing a loss of supply.

8.9 The Health and Safety Executive confirmed to this review that it is aware that National Grid Electricity Transmission submitted two reports via the Health and Safety Executive online portal under ESQCR: the first for the 'large supply interruption' and the second for the 'major substation fire'.

8.10 The published guidance relating to ESQCR is from 2002. The Health and Safety Executive has informed this review that it is an ESQCR regulatory authority for matters relating to safety, along with other regulatory bodies. The Health and Safety Executive has confirmed it does this by utilising the Health and Safety at Work Act 1974 and the Electricity at Work Regulations 1989 to achieve compliance with ESQCR. This review has sought clarity as to the roles and responsibilities of the other regulatory bodies (as referred to by the Health and Safety Executive) relating to the 'safety' obligations under ESQCR, in particular regarding fires at substations. This review has not been able to confirm fully the other regulatory bodies in relation to wider obligations contained in ESQCR.

Recommendation: Electricity Safety, Quality and Continuity Regulations

6. Government and regulators should refresh guidance available on ESQCR, including clarifying roles and responsibilities.

System restoration

8.11 After the tripping of SGT3 at 23:21 and SGT1 at 23:49, the 275kV, 66kV and 22kV substations at North Hyde had no supplies.

8.12 Following discussions between SSEN Distribution, National Grid Electricity Transmission and London Fire Brigade, at 09:49 on Friday 21 March, North Hyde 66kV busbars were re-energised. This used interconnection to Iver 66kV substation, elsewhere on the SSEN Distribution network. This facilitated the full restoration of domestic customers, and the ability to provide supplies to Heathrow Substation A and other commercial customers (see paragraphs 11.17 - 11.18).

8.13 At 00:55 on Saturday 22 March, North Hyde 275kV substation's SGT2 was energised and connected to the wider transmission system. At 02:22, SGT2 was used to supply the 66kV bars at North Hyde. The 66kV interconnector circuits from Iver were switched out at this point to manage the flow on the circuits. This left North Hyde 66kV fed from a single transmission circuit.

8.14 NESO, National Grid Electricity Transmission and SSEN Distribution agreed a proposal to return the SGT4A and SGT4B circuits at Iver substation, which had been undergoing repairs following a fault in January and had already been planned to return to service on Saturday 22 March. The successful return of Iver SGT4A and SGT4B allowed the Iver network to be reconfigured with SGT4B switched and supplying load to two 66kV circuits from Iver to North Hyde from 19:22.

8.15 Following the return of SGT4A and SGT4B at Iver substation, the substation was reconfigured to allow two supergrid transformers to supply North Hyde 66kV substation via the 66kV interconnectors if needed, while the other two Iver supergrid transformers supplied the Iver 66kV load. In this arrangement, North Hyde 275kV substation SGT2 and the 66kV interconnectors could supply customer demand at North Hyde 66kV substation. This provided additional resilience to supply this demand.

8.16 North Hyde 275kV SGT1 and SGT3 remain out of service at the time of publication.

Operational communications

8.17 This review has seen evidence that National Grid Electricity Transmission, SSEN Distribution, NESO and Heathrow Airport Limited were in regular communication throughout Friday 21 and Saturday 22 March regarding the incident. Most of these communications were felt to be clear, effective, and collaborative by the parties involved.

8.18 However, notwithstanding the above, Heathrow Airport Limited reported to this review that, during the incident, it received conflicting messages from SSEN Distribution regarding the level of resilience that could be provided should it return to the pre-incident configuration of its private internal electrical distribution network. This review has listened to the communications between Heathrow Airport Limited and SSEN Distribution throughout the incident. This review finds that during the incident there was not a shared understanding of what was meant by a resilient supply between the two operators. This inhibited clear communication around changing network configuration actions and options. This review notes that Heathrow Airport Limited and SSEN Distribution are continuing to discuss this matter.

8.19 Following the incident, SSEN Distribution has continued to work with Heathrow Airport Limited to share information and analysis, to enable Heathrow Airport Limited to make appropriate decisions about the operation and configuration of its internal electrical distribution network and its connection to SSEN Distribution's network.

Incident management plans

8.20 Evidence submitted to this review by National Grid Electricity Transmission, SSEN Distribution, NESO and Heathrow Airport Limited indicates that all key stakeholders followed incident management plans, and that these plans operated largely as anticipated. Further information regarding Heathrow Airport Limited's specific incident response can be found in Section 9.

Convening relevant parties

8.21 Throughout the incident, there were two primary mechanisms by which the relevant parties were convened.

8.22 There were four senior industry calls chaired by the Department for Energy Security and Net Zero across Friday 21 March and Saturday 22 March. These were attended by National Grid Electricity Transmission, SSEN Distribution, NESO, and Ofgem. Heathrow Airport Limited joined the fourth of these calls on 22 March. These were in addition to Department for Energy Security and Net Zero convened cross-Whitehall meetings for relevant government departments and Ofgem.

8.23 An operational coordination forum was also then set up to facilitate the sharing of information among stakeholders. Attendees included National Grid Electricity Transmission, SSEN Distribution, Heathrow Airport Limited, UK Power Networks Services, the Department of Energy Security and Net Zero, the Department for Transport, and Ofgem. The first meeting of this forum was held on Monday 24 March and was chaired by NESO's Director of System Operations. It sought to address short-term resilience in transmission and distribution infrastructure, current asset configurations, and plans for improvements specifically for the North Hyde site. Heathrow Airport Limited told this review that it found the meetings beneficial in enabling a greater understanding of the upstream resilience picture.

8.24 While these two channels demonstrate opportunities for relevant parties to communicate and collaborate, the operational coordination forum had not been planned for prior to the incident. This meant that there was initially no mechanism to bring together all relevant operational parties for effective technical cooperation.

Recommendation: Incident management protocols

7. For every CNI site, incident management protocols should explicitly include plans around loss or impairment of energy supplies. These protocols should include a mechanism to convene all relevant parties (including network companies, system operators, regulators, government etc. as appropriate).

9. Heathrow Airport

9.1 This section presents this review's analysis and recommendations relating to the impact of the incident on Heathrow Airport, including the configuration of its private internal electrical distribution network, the extent to which Heathrow Airport Limited had planned for a loss of supply, and the opportunities provided to increase resilience through its three independent supply points.

Key messages

- The design and configuration of Heathrow Airport's private internal electrical distribution network meant that the loss of one of its three independent supply points would result in the loss of power to operationally critical systems, leading to a suspension of operations for a significant period.
- This situation was understood by Heathrow Airport Limited and there were plans in place to respond to such an event. These plans included the reconfiguration of the network, with an estimated timescale of 10-12 hours.
- Heathrow Airport Limited stated that, in line with its wider regulatory obligations, it prioritised the safety of its staff and passengers, and security of the airport, by ceasing operations following the power outage. Its primary objective was then to resume operations as soon as it was safe to do so.
- This review finds there are opportunities, provided by having three independent supply points, to enhance the level of resilience and operational continuity of Heathrow Airport's private internal electrical distribution network.
- NESO, National Grid Electricity Transmission and SSEN Distribution stated to this review that they were not previously aware of the detail of Heathrow Airport's internal electrical distribution network configuration, or the potential impact of losing a supply point.

Loss of power and airport closure

9.2 At 23:49 on Thursday 20 March, power was lost to Heathrow Substation A, meaning power was lost to some airport terminals and some shared systems required for overall airport operations. Heathrow Airport's airfield ring generators automatically started to maintain supplies to the runways and essential safety systems, maintaining the ability to land aircraft safely. Power continued to be supplied to Heathrow Substations B and C.

9.3 At 00:03 on Friday 21 March, Heathrow Airport Limited called SSEN Distribution and was informed of the power supply interruption. At 01:11, Heathrow Airport Limited's Chief Operating Officer took the decision to close Heathrow Airport. The impact of the power outage on some of Heathrow Airport's operationally critical systems played a key role in this decision.

Restoration

9.4 At 01:56, SSEN Distribution advised Heathrow Airport Limited that there was no supply available to Heathrow Substation A, and that supplies were unlikely to be restored in the next five hours. In response, Heathrow Airport Limited, using its pre-prepared resilience plan as a starting point, developed a plan to reconfigure its internal electrical distribution network.

9.5 From 02:00 on Friday 21 March, Heathrow Airport Limited's Airport Control Engineer began to re-energise terminals and other impacted systems, which had lost supplies from Heathrow Substation A (having been fed from North Hyde 66kV substation). Heathrow Airport Limited's engineers used interconnections between Heathrow Airport's remaining two unaffected supply points.

9.6 As part of its incident response, via discussions with SSEN Distribution's control centre, Heathrow Airport Limited explored the possibility of paralleling its network with the higher voltage SSEN Distribution network. Heathrow Airport Limited was informed by SSEN Distribution that this would require power system studies before it could be implemented to assess the risk of high power flows which could damage assets on Heathrow Airport's internal electrical distribution network. Consequently, this option was not available to Heathrow Airport Limited during the incident.

9.7 All of Heathrow Airport's primary 33kV substations connected to Heathrow Substation A were re-energised by 06:25, following which Heathrow Airport Limited's engineers re-energised the wider network of around 300 low voltage substations. By 10:56 it was confirmed that power had been restored to all of Heathrow Airport's terminals and re-energisation of the wider Heathrow Airport Limited network was completed by 14:23.

9.8 Once power had been restored, there was a period of safety checking to allow all parties operating the airport to access their systems and to ensure safety critical systems were fully operational prior to passengers arriving at the airport. Heathrow Airport Limited noted to this review the potential risk to passenger health and safety had the airport been open to passenger arrival prior to these checks taking place.

Understanding of risk and restoration

9.9 Heathrow Airport Limited's expectation of a resilient energy supply prior to the incident was that it would have an 'uninterruptable' supply to each of its supply points, except for limited supply interruption scenarios.

9.10 This review has seen that, prior to the incident, Heathrow Airport Limited had identified that power disruption could 'greatly impact operations'. However, Heathrow Airport Limited assessed the total loss of power to one of its three supply points as a high-impact, low-probability event.

9.11 Heathrow Airport Limited had mitigations in place to manage the risk it identified. This included retaining trained engineers on site, having 24-hour support from UK Power Network Services, and developing a specific incident response plan and switching schedule for the loss of high voltage power to each of its supply points. This review has seen no evidence to suggest that Heathrow Airport Limited had exercised its response to this particular scenario (i.e., the unplanned loss of a single supply point), although Heathrow Airport Limited has provided evidence of other power outage exercising it has undertaken.

9.12 Heathrow Airport Limited had additional mitigations on its risk register relating to the impact of, and ability to respond to, power disruption. One mitigation concerned installing a 33kV ring, which could increase network flexibility and resilience. As Heathrow Airport's three supply points cannot currently run in parallel, this review is of the opinion that a 33kV ring could improve resilience and reduce restoration time following an outage, but it would not eliminate the risk of disruption entirely when considered in isolation.

9.13 A second mitigation recognised the inability to parallel Heathrow Airport Limited's network between connection points due to risks of high power flow and technical challenges of interconnecting separate areas of SSEN Distribution's distribution system through Heathrow Airport's internal electrical distribution network.

9.14 This review finds that neither of these mitigations has been fully explored or implemented.

9.15 As such, this review has seen evidence that the risk of power disruption, and risk associated with Heathrow Airport's limitations in being able to respond to power disruption, were known to and accepted by Heathrow Airport Limited as a high-impact, low-probability event.

9.16 Following the incident, Heathrow Airport Limited commissioned a review ("The Kelly Review"). According to the Kelly Review, 'whilst the overall risk of a loss of supply had been appropriately understood, details about the length of the possible outage and precise impact on systems in this scenario were less well-known by those outside the technical team' within Heathrow Airport Limited. During the incident, the manual reconfiguration of Heathrow Airport's internal electrical distribution network occurred within the 10–12 hour window expected by the technical team.

9.17 The Kelly Review states that enhancements to processes are underway so that high-impact, low-probability risks can be subject to increased oversight by Heathrow Airport Limited's functions and leadership.

Opportunities to enhance resilience

9.18 The loss of supplies from one of Heathrow Airport's supply points was not deemed a likely scenario by Heathrow Airport Limited due to its expectation of the resilience of the wider network. This meant that its internal electrical distribution network was not designed or configured in such a way as to take advantage of having multiple supply points to provide quick recovery following such a loss and was reliant on manual switching.

9.19 It is the view of this review that the ability to either connect or automatically switch load between Heathrow Airport's supply points may have aided in resecuring its network for the loss of supplies without interrupting critical functions and would have, as a minimum, reduced the restoration time. This is an example of the value provided by considering flexibility in the development of electrical networks and systems, not just capacity.

9.20 Comprehensive technical assessments would be needed to determine the best way forward. This review is aware that SSEN Distribution is assisting Heathrow Airport Limited by providing information, network studies, and expertise to enable Heathrow Airport Limited to consider the potential options to make its internal electrical distribution network more resilient to an event of this nature.

Awareness of Heathrow Airport's internal electrical distribution network

9.21 This review has seen evidence that National Grid Electricity Transmission, SSEN Distribution and NESO shared a common understanding that North Hyde substation supplied Heathrow Airport. However, these parties have stated to this review that they were not previously aware of the detail of Heathrow Airport's internal electrical distribution network configuration, or the potential impact of losing supply to Heathrow Substation A. This review is not aware of any regulatory obligation for these parties to have obtained knowledge of Heathrow Airport's internal electrical distribution network configuration or any potential impacts of losing supply.

9.22 Following the incident, National Grid Electricity Transmission has initiated a strategic demand review to increase its understanding of the inherent resilience of strategically important demands, and to enhance engagement with key stakeholders. This work will lead to site specific recommendations for any remedial actions identified from high-impact, low-probability event assessments, and/or from a view of collective risk on any one site. National Grid Electricity Transmission has identified a number of sites to initiate the review. This review assesses there would be significant value in this work being coordinated across other transmission and distribution owners, NESO, Ofgem, and government.

Recommendation: Resilience of infrastructure with multiple supply points

8. Where a CNI or essential service site has multiple supply points connected to the energy system, explicit consideration should be given by the site operator to the level of resilience and operational continuity required, and how this can be achieved.

   This could include:

   i) Diversifying the configuration such that the loss of one supply point does not impact the entire CNI site.

   ii) The ability to switch load quickly between the supply points. For example, on the electricity system (e.g., via internal interconnectors, automatic/tele switching) and, where appropriate, the use of short duration uninterruptable power supply while switching takes place such that operations can be maintained.

Heathrow Airport's current network configuration

9.23 Details relating to the current configuration of Heathrow Airport's internal electrical distribution network are provided separately in Appendix F. Due to its sensitivity, this appendix is strictly confidential and is therefore redacted from publication. However, the detail set out in that appendix does not impact the analysis or recommendations made in this report.

10. Critical National Infrastructure

10.1 **This section presents this review's analysis and recommendations relating to the wider relevance of energy resilience to Critical National Infrastructure (CNI), including how cross-sector interdependencies are mapped and understood.**

Key messages

- Today, energy network operators are not aware whether customers connected to their networks are classified as CNI. Work is underway to identify and analyse cross-sector interdependencies.
- There is currently no cross-sector requirement on CNI operators to ensure specifically the continuity of operations in response to power disruption.
- The Cabinet Office process to identify the criticality of each CNI operator and any resultant resilience requirements are not currently underpinned by any cross-sector legislation or regulation.

Critical National Infrastructure

10.2 The UK government identifies critical elements of UK infrastructure through the Cabinet Office's Critical National Infrastructure policy.

Critical National Infrastructure

CNI is defined by the UK government as 'the critical elements of infrastructure (namely assets, facilities, systems, networks or processes and the essential workers that operate and facilitate them), the loss or compromise of which could result in:

- Major detrimental impact on the availability, integrity, or delivery of essential services - including those services whose integrity, if compromised, could result in significant loss of life or casualties - considering significant economic or social impacts; and/or
- Significant impact on national security, national defence, or the functioning of the state.'

10.3 The CNI framework aims to identify and protect these essential services. There are 13 CNI sectors, namely:

- Chemicals
- Civil Nuclear
- Communications
- Defence
- Emergency Services
- Energy
- Finance
- Food
- Government
- Health
- Space
- Transport
- Water

10.4 The methodology to assess the criticality of assets and how that applies across CNI is owned by the Cabinet Office. Each CNI sector's lead government department is responsible for applying the CNI Criticalities methodology, which can involve developing detailed technical criteria for some sectors (including energy). This is to identify and assess what is important in their respective sectors, and to then designate critical elements as CNI depending on their potential to have a major detrimental impact. In line with NESO's licence conditions, NESO will provide advice on proposed CNI methodologies for the energy sector and apply them once approved to energy assets.

10.5 This information is extremely sensitive, given its possible national security implications. The majority of CNI operators are notified of their own designation, however operators are unlikely to be aware of each other's CNI status in the current process. By extension, energy network operators are today not aware of whether customers connected to their networks are classified as CNI.

Cross-sector interdependencies

10.6 While the 13 identified CNI sectors each provide crucial services, some sectors are also interdependent, and energy is a common dependency across all sectors. Noting the increasing challenge of managing resilience in this context, the UK government expanded its CNI methodology in 2020 to gather data on the links between sectors to manage better the risks faced by the UK.

10.7 The Cabinet Office, National Cyber Security Centre and National Protective Security Authority have developed the CNI Knowledge Base, a tool that seeks to map CNI infrastructure. This work programme is envisaged as a 'single source of truth' for CNI, to enable government analysts to visualise criticalities and understand interdependencies across sectors.

10.8 The CNI Knowledge Base is underpinned by a common approach, such that each of the 13 CNI sector's lead government departments collect and structure CNI data in a shared way, meaning they are comparable. The approach maps the critical essential functions delivered by each sector. It determines what assets and systems are critical to delivery of the function, the impact of that asset or system's failure, and aims to map cross-sector dependencies, and therefore cross-sector cascading impacts.

10.9 Lead government departments are in the process of undertaking this work. However, the Cabinet Office reported to this review that the final step, assessing cross-sector impacts, is yet to be completed. It is not currently known how long this process will take, as it relies on full contributions from all lead government departments, and significant voluntary input from CNI operators.

10.10 The completion of this process would enable government to visualise full dependencies and single points of failure that exist between the energy sector and other areas of CNI. The Cabinet Office recognised to this review a need to accelerate the progress of this activity. This review is of the opinion that the completion of this work could, in turn, inform government's approach to cross-sector resilience, with the potential to reduce both the likelihood and impact of disruption to power, as seen in this incident.

Energy resilience

10.11 Through engagement with lead government departments, this review identified that whilst there was commonality in interpretations of energy resilience across CNI sectors, some areas of difference were also identified. This review has found that energy resilience is not specifically emphasised by the Cabinet Office or lead government departments in resilience requirements for CNI operators. Instead, resilience and business continuity are referred to more generally, and are threat and risk agnostic. Some sectors, such as aviation within transport, have a strong focus on safety, whilst others, such as water and telecommunications have a focus on minimising overall impact to customers.

10.12 There is some sector specific legislation requiring owners or operators to ensure the continuity of essential services, for example the Water Industry Act 1991 and Security and Emergency Measures Directions 2022 (for the water sector), the Network and Information Systems Regulations 2018 (covering multiple CNI sectors), and the Space Industry Regulations 2021 (for the space sector).

10.13 However, there is currently no explicit cross-sector requirement on CNI operators to ensure CNI resilience to power disruption, or to set standards of energy resilience. The Resilience Framework, published by the UK government in December 2022, sets a requirement to implement standards where this is deemed necessary. This review considers that in light of the increasing criticality of energy to all other CNI sectors, this is a gap in existing CNI policy.

10.14 The CNI Criticalities process and any resultant resilience requirements are not currently underpinned by cross-sector legislation or regulation. There is some sector specific legislation, for instance the Water Industry Act 1991 and Security and Emergency Measures Directions 2022 which set out expectations tied to water sector CNI asset categorisation. Additionally, electricity system and network operators are generally prohibited through their licence conditions from discriminating between customers, which means that a CNI operator is not treated any differently in terms of connection, service, or restoration from any other domestic or commercial customer.

Recommendations: Energy resilience of CNI

9. CNI operators should be able to have transparent conversations, then work together with energy networks (transmission and/or distribution as appropriate) and system operators to review and establish a mutual understanding of the resilience and security of the energy supply arrangements to the CNI site.
10. CNI operators should develop a communication and operational protocol for addressing any planned and unplanned changes to resilience.
11. NESO and the government should work together to develop an appropriate holistic view of the CNI reliance on the energy system.
12. CNI operators, government and the relevant regulatory bodies should establish a more structured approach to energy resilience, for example via cross-sector partnerships and standards, including standards around continuity of operations under various scenarios (e.g., loss of an energy asset).

11. Customers

11.1 **This section presents this review's analysis relating to the impact of the incident and subsequent restoration on domestic and commercial customers, the effectiveness of communication with these customers, and the incident's impact on the local area.**

Key messages

- The outage at North Hyde led to 71,655 domestic and commercial customers losing power. 179 people were evacuated because of the fire and a small number of people had to be provided with alternative accommodation.
- During the incident, relevant parties communicated effectively with the public using media statements and social media.
- SSEN Distribution restored power to its 66,919 customers within expected timeframes. SSEN Distribution communicated effectively with its domestic customers throughout the incident, including with those on its Priority Services Register.
- Some commercial customers have told this review that the communications they received were less coordinated and effective.
- The impact to the local area, including road, rail, and the environment, was relatively contained.

Expectations of electricity supply in Great Britain

11.2 Great Britain has one of the most reliable energy systems in the world with comparatively few supply disruption events affecting consumers.

11.3 Individual supply points, including the three at Heathrow Airport, are connected to networks that are designed to the minimum standards set by both the SQSS and Engineering Recommendation P2, as described in Section 8 and Appendix E. These standards stipulate a required level of redundancy (i.e., an ability to cope with one or more pieces of equipment being out of service) but do not guarantee a level of resilience for an individual supply point.

11.4 Reliability in Great Britain is generally high and is monitored continually. In 2023/24, the last full year of reporting, the overall reliability of supply for the National Electricity Transmission System in Great Britain was reported as 99.999930%. Outages can occur as a result of faults, maintenance or emergencies and 100% uninterrupted supply cannot be guaranteed. Licence holders have a legal duty to develop and maintain an efficient, coordinated, and economical system. In addition, network owners are encouraged to minimise supply interruptions through financial mechanisms within their respective transmission and distribution licences.

11.5 The National Terms of Connection states that 'The right to be (and remain) Connected does not include the right to be (and remain) Energised'. The National Terms of Connection also outlines circumstances where it is reasonable that supply can be de-energised.

11.6 Some commercial customers may have connection agreements which have bespoke supply arrangements, however these would be in addition to the legal and regulatory obligations and could not contravene them. In other words, the network operator must still act in compliance with its legal and regulatory obligations, including those related to minimum engineering standards, safety, and non-discrimination principles.

Local impact

11.7 There were no injuries or fatalities as a result of the fire, either to members of the public, employees, or the emergency services.

11.8 The outage at North Hyde led to 71,655 domestic and commercial customers losing power. 179 people were evacuated as a result of being in the vicinity of the fire. The London Borough of Hillingdon confirmed 12 people were placed in accommodation and a rest centre was set up at Botwell Library, which opened at 06:00 on Friday 21 March.

11.9 Hillingdon Hospital and four GP surgeries were affected by the outage. London Ambulance service lost power to two satellite stations at Hayes and Heathrow resulting in the loss of secure drugs rooms causing logistical impacts. However, there were no reported patient impacts directly resulting from the outage.

11.10 Open-source information from Hillingdon Council indicates the power outage affected various public institutions and services in the surrounding area, including schools and refuse and recycling collections.

11.11 The fact the incident occurred overnight meant there was a lower likelihood of employees being present at the North Hyde substation. It also meant that impacts to the local area, including road and rail, were lower than may have been the case had it occurred during the day.

Public communication

11.12 During the incident, relevant parties communicated effectively with the public using media statements and social media.

11.13 Heathrow Airport Limited released its first statement at 02:14 on Friday 21 March announcing the airport's closure. Further statements, including communicating when it intended to reopen for business-as-usual operations, were released throughout that day.

11.14 National Grid Electricity Transmission released media statements throughout Friday 21 March, coordinating as appropriate with the Metropolitan Police Service. By 21:00 that evening, media focus had shifted to the cause of the incident, at which point National Grid Electricity Transmission declined broadcast requests given the lack of new information.

11.15 SSEN Distribution noted that its external media engagement was light, as it considered that National Grid Electricity Transmission was the 'lead energy spokesperson' given the incident initiated on the 275kV substation at North Hyde. Similarly, NESO did not consider itself the lead communications body, but did establish a holding social media post at 08:03 on Friday 21 March and then directed media queries to both National Grid Electricity Transmission and SSEN Distribution throughout the day.

SSEN Distribution customers

11.16 The outage led to a total of 71,655 domestic and commercial customers losing power. Of these, 66,919 were SSEN Distribution's domestic and commercial customers.

11.17 At 00:06 on Friday 21 March, SSEN Distribution began work to restore supplies to its customers using interconnections with substations that were not affected by the outage. By 00:47, SSEN Distribution had restored approximately 42,000 customers using 22kV and 11kV interconnections. Restoration of customers continued using these interconnections until 04:00 when available capacity on these cables was fully utilised, and 4,868 domestic customers remained without supplies.

11.18 By 08:30, over 62,000 customers had been restored, and by 12:24 all except two of the 66,919 domestic and commercial customers directly supplied by SSEN Distribution had power restored following the re-energisation of North Hyde 66kV. The two customers which remained off supply were able to utilise their own backup generators for supply while SSEN Distribution continued to support restoring their supply back to the network. Maps illustrating the restoration timeline of SSEN Distribution's customers are shown in Figures 8–12.

11.19 As set out in paragraph 8.7, SSEN Distribution has confirmed to this review that supplies were restored within the timelines required as set out in the applicable standards. This review agrees with this statement.

11.20 Information seen by this review suggests communication between SSEN Distribution and its domestic customers was effective and timely. SSEN Distribution ensured it liaised directly with all customers on its Priority Services Register, who may be particularly vulnerable in the event of power outages, providing an update via mobile and landline text by 03:37 on Friday 21 March. Phone queues were dealt with effectively, with SSEN Distribution responding to calls received in its Customer Contact Centre in an average of 69 seconds.

Maps of SSEN Distribution customer restoration

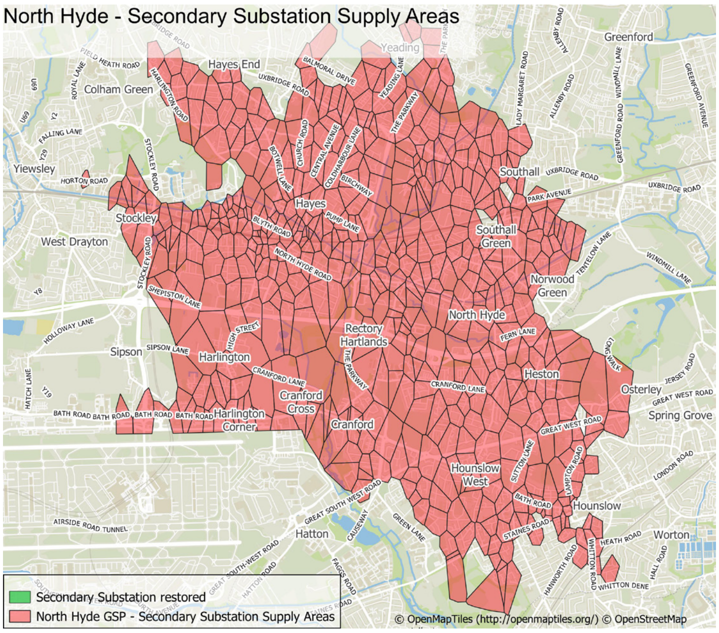

Figure 8: North Hyde secondary substation supply areas

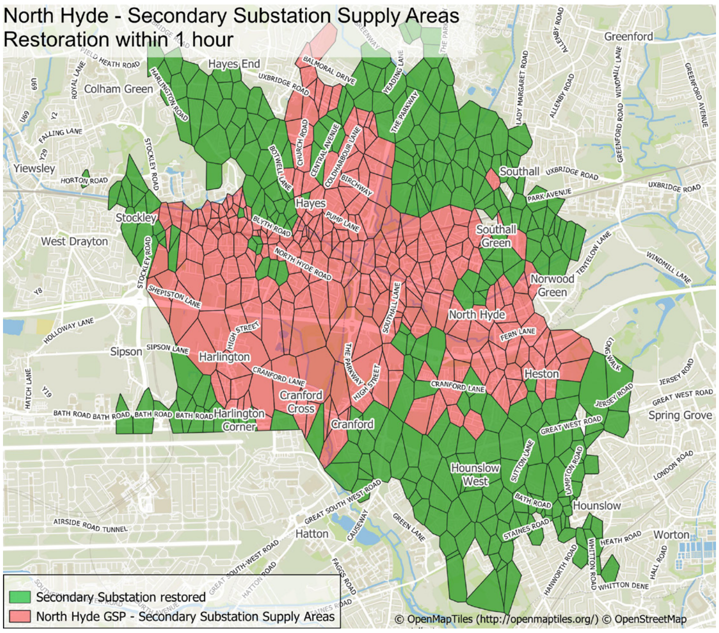

Figure 9: Secondary substation supply areas restored within 1 hour

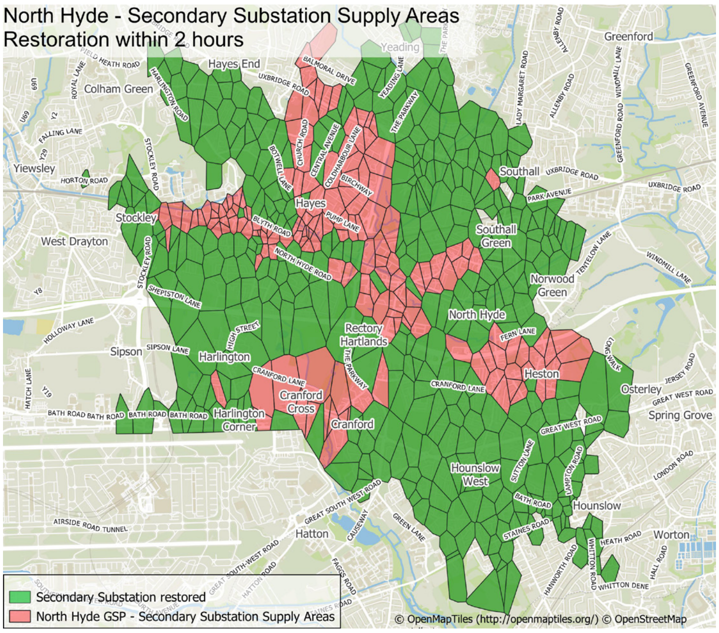

Figure 10: Secondary substation supply areas restored within 2 hours

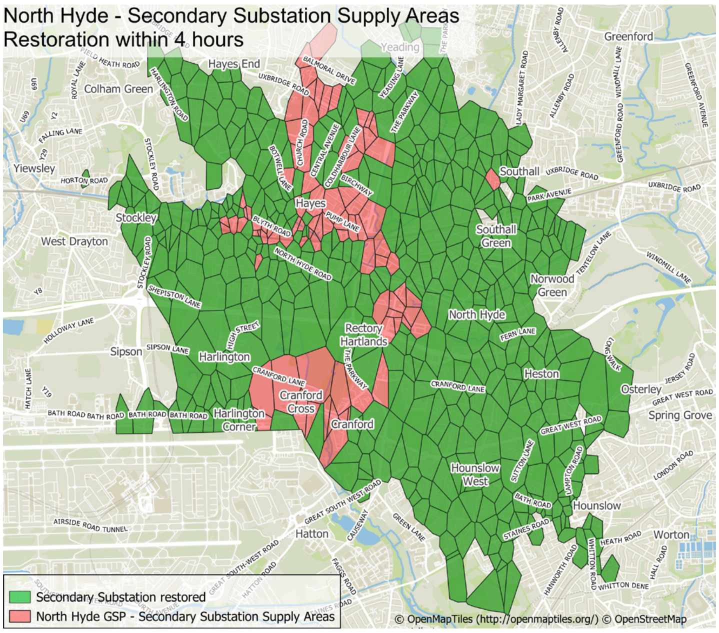

Figure 11: **Secondary substation supply areas restored within 4 hours**

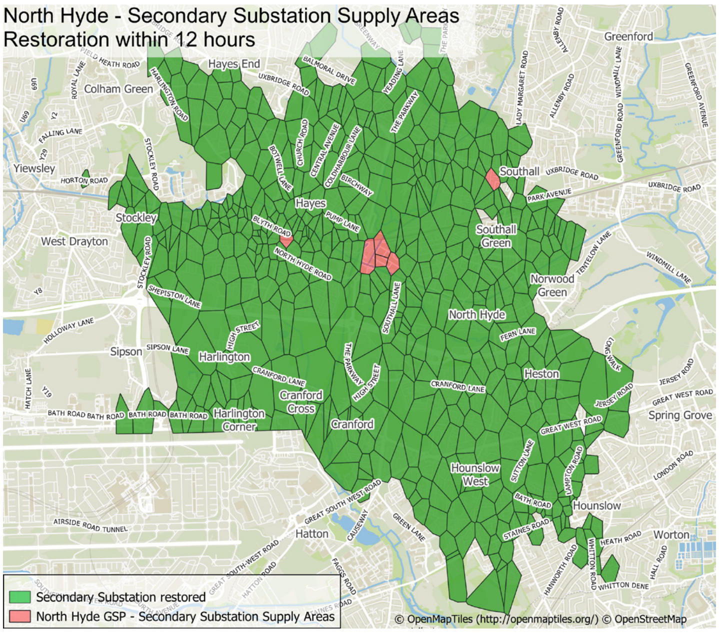

Figure 12: **Secondary substation supply areas restored within 12 hours**

Independent Distribution Network Operators' customers

11.21 An additional 4,736 domestic and commercial customers of Independent Distribution Network Operators also lost power during the incident. Independent Distribution Network Operators design, own, operate and maintain electricity networks, typically in smaller local areas.

11.22 Three Independent Distribution Network Operators were directly impacted by the incident, GTC, ESP, and Energy Assets. Power was restored to these customers by 15:00 on Friday 21 March. Due to uncertainty regarding when power would be restored, GTC took the decision to hire generators to restore electricity supply to its customers.

11.23 GTC told this review that reactive communications occurred between its control centres and those of SSEN Distribution, describing information it received as 'unclear' and 'sporadic'. GTC reported using existing relationships to supplement formal communication. Independent Distribution Network Operator ESP reported that it expected direct communications but ultimately identified information through SSEN Distribution's website and by proactively initiating contact with SSEN Distribution via phone calls. Energy Assets also noted no direct contact from SSEN Distribution.

11.24 SSEN Distribution told this review that all information shared was reflective of the situation at the point in time. SSEN Distribution stated that obtaining updates from its website and via phone calls is testament to the effectiveness of SSEN Distribution's multi-channel emergency customer communications plan.

Data centres

11.25 Amongst the commercial customers impacted by the incident were three large data centres: Ark, Virtus, and CyrusOne. Although these data centres lost supplies from North Hyde, they were able to remain operational by using their own backup generators.

11.26 With backup generators providing power to maintain operations, SSEN Distribution asked the data centres to stay disconnected or be re-energised ensuring no more than 1MW demand was utilised, until SGT2 was re-energised. The data centres told this review that they continued to use backup generation until they were satisfied their demand could be met in full.

11.27 Virtus and CyrusOne told this review that during the initial stages of the incident, they gathered updates using the SSEN Distribution portal. Both parties stated they would have preferred direct formal communications from SSEN Distribution during this period. However, this review notes that both sites were visited by SSEN Distribution engineers later on Friday 21 March when further information was given regarding the loss of supply. SSEN Distribution again states that obtaining updates from its website is testament to the effectiveness of SSEN Distribution's multi-channel emergency customer communications plan.

Road and rail

11.28 There were a number of roads in the area impacted by the power outage and emergency response to the fire, including closures to North Hyde Road, A312 Parkway, and the M4 southbound from Junction 4 to Heathrow tunnel. National Highways roadside technology devices (the tools and systems to improve traffic flow, monitor conditions and increase safety for road users) were initially affected but were restored after approximately two hours. Twelve bus routes were diverted and around fifteen traffic signal sites lost power in the Hayes Town area. Power was restored incrementally, with most traffic signal sites back online by 05:23 on Friday 21 March.

11.29 Transport for London was impacted in several ways. On the London Underground, the Piccadilly line stations of Hounslow Central and Hounslow West lost power and had to be closed. On the Elizabeth line, the stations of West Drayton, Hayes & Harlington, and Southall lost power, resulting in the closure of Hayes & Harlington and Southall stations. Power to all these stations was restored at around 01:26 on Friday 21 March, however, Hayes & Harlington Station was unable to immediately reopen due to loss of lighting. These issues were resolved later that morning. It is important to note that only the stations were affected, and that Piccadilly line and Elizabeth line trains were able to continue operating throughout this time and serve other stations.

11.30 Transport for London reported no direct communications from National Grid Electricity Transmission or SSEN Distribution. All these parties did attend Strategic Coordination Group meetings established in response to the incident by London Resilience Unit. This review notes that there was a misalignment between expectations of what information would be available throughout the incident, and how and from whom it would be provided.

11.31 As above, Transport for London was invited to Strategic and Tactical Coordinating Groups, coordinated by London Resilience Unit, which took place across Friday 21 March, and real-time information was shared with and between the Metropolitan Police Service, British Transport Police, and the London Situational Awareness Team for interagency coordination. Transport for London reflected that the London response was well coordinated, but that the incident brought into focus the need to understand wider network resilience for ongoing operations.

11.32 Network Rail's infrastructure was also affected. The signalling at Southall, Hayes & Harlington and West Drayton stations was impacted. At 02:50 on Friday 21 March it was reported that all power had been restored to the signalling. Trains could not run to Heathrow Airport's Terminal 4 station as fans and water pumps in the Heathrow tunnel were not working, although the airport was closed at this point in time. SSEN Distribution provided Network Rail with regular updates throughout the incident.

11.33 SSEN Distribution asked Network Rail to maintain its demand supply from its alternative connections. This arrangement was contingent on the North Hyde connection being available for Network Rail's use in an emergency or when necessary for planned demand sharing. Network Rail did not raise concerns about this instruction as it had alternative feeds.

NATS

11.34 National Air Traffic Services (NATS) was also impacted in several ways. At Heathrow Airport, the impact to air traffic control services was managed through a combination of uninterruptable power supply supporting the equipment until power was restored at 01:10 on Friday 21 March, and NATS putting a temporary generator in place following the incident to provide additional resilience. NATS also supported the diversion of 121 inbound flights as a result of the incident, in line with its pre-existing incident response plans.

Environment

11.35 National Grid Electricity Transmission states that following the incident, there was evidence of oil from the oil-filled equipment at North Hyde entering watercourses. National Grid Electricity Transmission told this review that it deployed emergency spill response within hours of the event, limiting the impact and controlling any further oil entering the watercourse. The Environment Agency was engaged and visited the North Hyde site on Saturday 22 March. No further enforcements or additional actions were recommended.

11.36 UK Health Security Agency was contacted with queries regarding safety of water supplies. Thames Water confirmed water sampling took place, and no impact was detected in the local watercourses.

11.37 London Fire Brigade used firefighting foam to tackle the fire, ensuring it was captured within the bund to prevent environmental escape. It conducted an environmental impact assessment, and the Environment Agency confirmed that the impact was minimal. Additionally, the site had an interceptor to prevent contaminated runoff from escaping into the environment.

11.38 There were concerns raised about the foam potentially containing per- and poly fluoroalkyl substances. Adler & Allan, contracted by National Grid Electricity Transmission, is an environmental risk reduction consultancy. It monitored environmental impacts on-site and conducted chemical tests to confirm the composition of the foam. The foam was found to contain per- and poly fluoroalkyl substances compounds, at levels below three per cent. This level is still classified as hazardous waste and potentially harmful to the environment, though not considered dangerous to people. As a result, tankers were deployed to pump and store the wastewater for processing off site.

11.39 London Fire Brigade has told this review that the foam used was the appropriate firefighting strategy for an oil fire and was compliant with legislation. Firefighting was undertaken with support from London Fire Brigade's Hazardous Materials & Environmental Protection Officer, who completed an environmental risk assessment which also considered control measures.

Next steps and acknowledgments

12. Implementation plan

12.1 **This review has focussed on the incident at North Hyde and has sought to draw out from this event recommendations to improve the resilience of Critical National Infrastructure (CNI) and essential services to power disruption. These recommendations will require close cooperation across industry, regulators, and lead government departments to ensure they are effectively implemented. For this reason, they have been developed to be outcome focussed, rather than tactical, so that relevant parties can collaborate to consider the most appropriate, proportionate means of achieving the outcome in a way that can be scaled and, ultimately, improve energy resilience across the UK.**

12.2 With previous reports into large scale power disruption (for example, the Great Britain Power System Disruption on 9 August 2019 report and the Energy Emergencies Executive Committee Storm Arwen Review), this collaboration was achieved through the development of task groups within existing structures where industry, regulators, and lead government departments already meet and work together.

12.3 This review proposes that a similar approach is taken and that where there are existing structures they are utilised to identify and develop the actions, owners and timeframes required. However, we recognise that the recommendations in this report will apply to a number of CNI sectors and organisations and it will be for the relevant government departments or public bodies to decide their approach.

12.4 NESO recognises that many of those affected have already held internal reviews and identified lessons. Heathrow Airport Limited published its own Kelly Review and has committed to implementing those recommendations in full. Work has already begun within National Grid Electricity Transmission and SSEN Distribution to identify actions that will support implementing the recommendations of this review. For example, National Grid Electricity Transmission has initiated five workstreams aimed at delivering improvements to its processes around risk management. SSEN Distribution has also been proactively engaging with Heathrow Airport Limited to support it to build its resilience following the incident.

12.5 Looking ahead, NESO's role will be increasingly important in helping to ensure a resilient energy system, taking into account its complex interdependencies with other critical systems. In particular, this review highlights the criticality of energy to CNI, and the significant value that could be realised in bringing together cross-sector parties to build relationships, and, ultimately, form a shared understanding of energy resilience.

12.6 Where appropriate, NESO will work with DESNZ, as the lead government department for energy, Ofgem, and Cabinet Office, to develop the implementation approach to recommendations for improvements to CNI energy resilience. This collaboration will aid government in refining its understanding and tolerance of energy risks, which is a key part of wider national resilience.

13. Acknowledgements

13.1 **The response to the incident itself and the enquiries that have followed have involved numerous organisations, each playing a different role. The quantity of information and data that has been reviewed as part of this investigation, combined with a common desire to understand what happened, will help to minimise the chances of it happening again.**

13.2 This review would like to thank all individuals and organisations who contributed to this report:

- Ark
- Cabinet Office
- Civil Aviation Authority
- CyrusOne
- Department for Business and Trade
- Department for Energy Security and Net Zero
- Department for Environment, Food and Rural Affairs
- Department for Science, Innovation and Technology
- Department for Transport
- Department of Health and Social Care
- Energy Networks Association
- GTC
- Health and Safety Executive
- Heathrow Airport Limited
- HM Treasury
- Independent Networks Association
- London Fire Brigade
- London Resilience
- Metropolitan Police Service
- Ministry of Defence
- National Cyber Security Centre
- National Grid Electricity Transmission
- National Preparedness Commission
- National Protective Security Authority
- NATS
- NESO
- Network Rail
- Ofgem
- Scottish and Southern Electricity Networks Distribution
- Scottish and Southern Electricity Networks Transmission
- Scottish Power Energy Networks
- Transport for London
- UK Power Networks Services
- UK Regulators Network
- Virtus

Appendices

A. Network design and history

A.1 This section describes how the network typically runs, and existing conditions immediately prior to the incident. It also provides further context on the design history of relevant elements of the electricity network, including the standards that must be met.

Design and history

North Hyde substation site

A.2 The North Hyde substation site is located east of Hayes, on the border of Hillingdon and Hounslow in West London. There are four substations at the site: the 275kV (controlled by National Grid Electricity Transmission) and the 66kV, 22kV and 11kV (all operationally controlled by SSEN Distribution). The site was commissioned by the Central Electricity Generating Board in 1968 to supply increasing demand in the Hayes and Heathrow areas, and to serve the expansion of Heathrow Airport through the late 1960s.

A.3 The site is located in an urban region with residential, commercial, and industrial areas. There are main transport links in the area surrounding the substation including railway, Heathrow Airport, and motorway (M4). There is also a canal to the north of the substation.

North Hyde 275kV

A.4 North Hyde 275kV substation is owned and operated by National Grid Electricity Transmission. It is an outdoor air-insulated substation compound. North Hyde 275kV is fed directly from Iver 275kV substation by two 275kV circuits, each connected to the high voltage busbars which in turn connect to the transformers and their associated switchgear.

A.5 There are three double-wound supergrid transformers within the North Hyde 275kV substation compound, which step voltage down from 275kV to 66kV. SGT1 and SGT3 were both manufactured by Hackbridge & Hewittic and installed with the 275kV substation in 1968. The third supergrid transformer, SGT2, is a newer Areva model, having been commissioned in 2010.

A.6 The North Hyde 275kV substation is designed to operate with two transformers on-load and the third on 'hot standby'. This is achieved using an autoclose scheme which operates following the loss of either of the two in service transformers, SGT1 or SGT3. The scheme is designed to switch SGT2 into service automatically if a problem is detected on either SGT1 or SGT3 which results in one of them having to be disconnected.

North Hyde 66kV

A.7 North Hyde 66kV is an outdoor two-section double busbar substation, with air-insulated switchgear. The 66kV substation was originally commissioned in 1968, concurrent with the connection of the first two supergrid transformers, SGT1 and SGT3. It was later extended in 1977/78 with the addition of four 66kV switchgear bays for the connection of the adjacent (now demolished) Bulls Bridge power station. Since the 1990s, several circuits have been added to the 66kV switch board in order to reinforce the local network.

A.8 National Grid Electricity Transmission owns the busbars and associated bus section and bus coupler bays at the North Hyde 66kV substation, as well as the common facilities, and is responsible for the physical management of the site. The majority of the circuits connecting to the North Hyde 66kV busbars site feed the distribution network and are owned by SSEN Distribution, with the rest of the circuits feeding either Network Rail or data centre demand and are owned by these parties. The site is controlled by SSEN Distribution's control room, which undertakes operational and safety switching at North Hyde 66kV substation on behalf of National Grid Electricity Transmission.

North Hyde 22kV

A.9 North Hyde 22kV substation is an indoor substation owned and operated by SSEN Distribution, located to the south of North Hyde 66kV substation. It is supplied by three 66/22kV circuits from North Hyde 66kV and can be connected through to the Laleham grid supply point group via East Bedfont. It supplies the North Hyde and Hayes area 11kV network.

Iver substation site

A.10 The Iver substation site is located close to Uxbridge, on the western edge of the London Borough of Hillingdon. There are three outdoor substations at the site: the 400kV and 275kV (controlled by National Grid Electricity Transmission), and the 132kV substation (controlled by SSEN Distribution). There is a further indoor 66kV substation, also controlled by SSEN Distribution.

A.11 North Hyde 275kV is fed directly from Iver 275kV substation by two 275kV circuits. Iver also supplies SSEN Distribution's demand in East Berkshire, South Buckinghamshire, and the London Borough of Hillingdon.

Heathrow Airport's private internal electrical distribution network

A.12 Heathrow Airport's private internal electrical distribution network has developed over a number of years as the airport grew. The network is fed from three supply points, referred to in this report as Heathrow Substation A, B and C. These substations each supply a different combination of terminals, the Airport Complexes (Eastern, Central and Western), Maintenance Areas, Cargo, and other key airport operations.

A.13 Heathrow Airport's three supply points run as independent nodes. Under normal operating conditions, there is minimal interconnection between the three and therefore manual switching procedures must be implemented to reconfigure the network if capacity needs to be moved from one supply point to another.

How the network runs

A.14 Prior to the incident, the network was configured as designed and operating within expected parameters. North Hyde 275kV was connected to Iver 275kV via two circuits and the supergrid transformers SGT1 and SGT3 were in service with approximately 100MVA in total (50MVA in each supergrid transformer) of power flowing through to the 66kV at North Hyde. SGT2 was on hot standby, with the system designed to switch the transformer into service automatically, should it be needed.

A.15 North Hyde 66kV was running 'solid', meaning it was functioning as a single gathering point for power flows. The 66kV interconnections with Iver 66kV were running as normal, open (disconnected) at North Hyde and closed at Iver so they could be connected to North Hyde when needed.

A.16 At Iver 66kV, three out of four 275/66kV transformers were in service. SGT4B (275/66kV transformer) and SGT4A (275/132kV transformer) had been out of service since 11 January 2025 due to a failure on the 275kV circuit breaker H40 at Iver 275kV (see Figure 13). At intact conditions, Iver 66kV substation is normally run on three SGTs, with the fourth on hot standby.

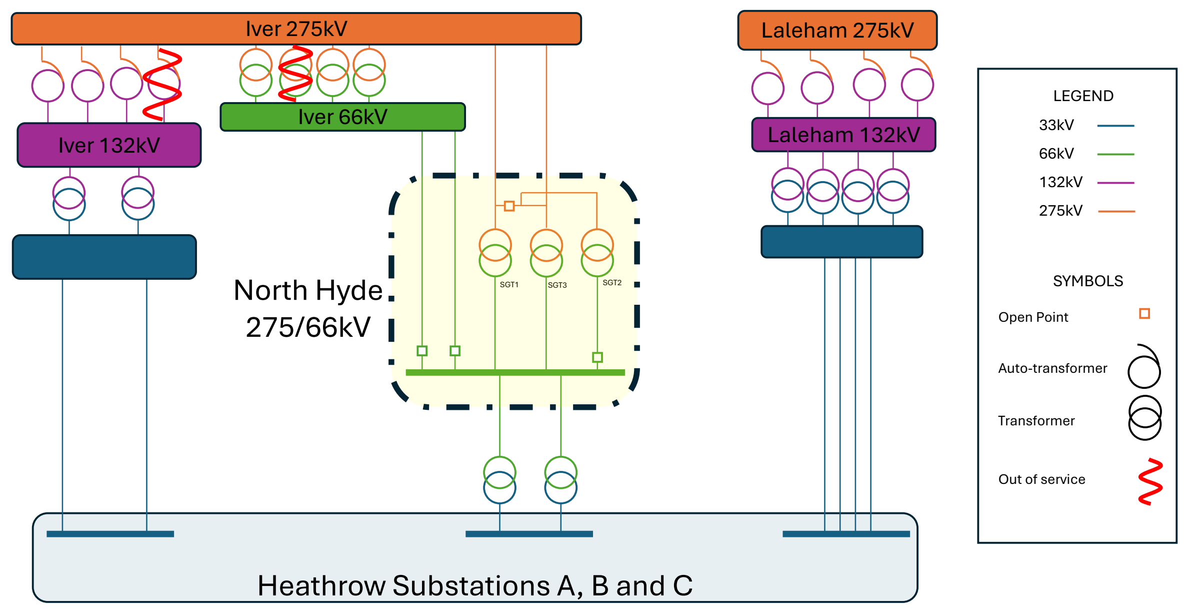

Figure 13: **Line diagram of Iver and North Hyde network prior to the incident**

A.17 Each of Heathrow Airport's three supply points is connected to the distribution network by at least two separate circuits. Any two out of the supply points have enough capacity to supply Heathrow Airport peak demand. Immediately prior to the incident, all three connection points were operating as normal.

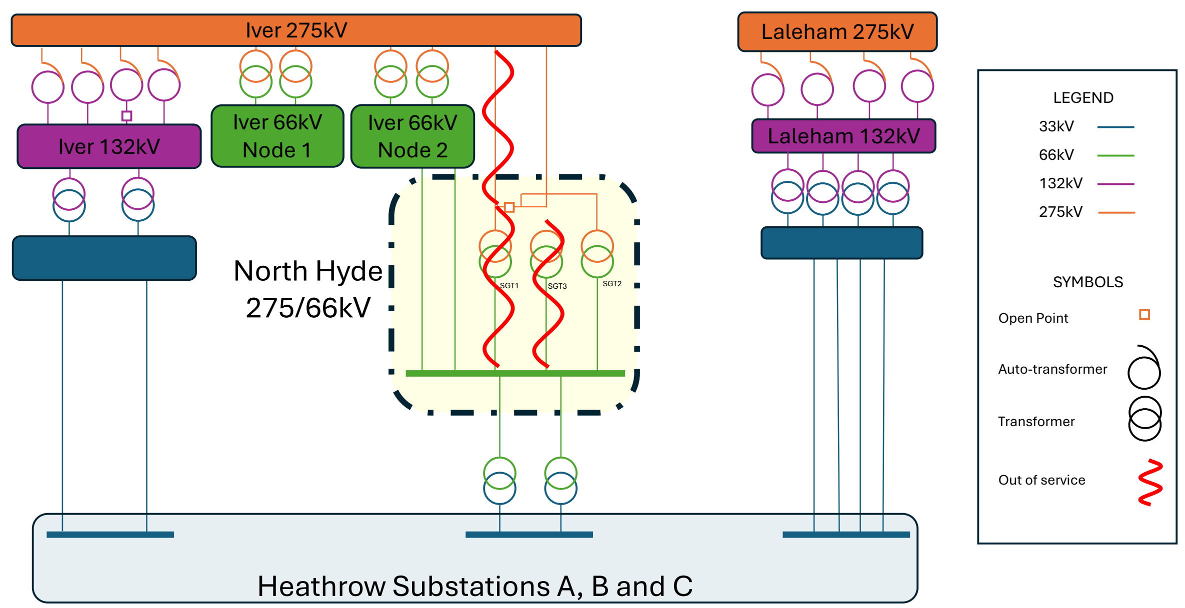

Figure 14: **Line diagram showing network configuration following the return to service of SGT4B and SGT4A at Iver substation**

B. Terms of Reference

B.1 The following Terms of Reference were set by the Department for Energy and Net Zero for NESO's review of the incident. These were published on Friday 28 March 2025 and are available on the Department for Energy and Net Zero's website.

Introduction

B.2 Late evening on Thursday 20 March 2025, a large fire broke out at North Hyde Electricity Substation in Hayes, London. This resulted in over 60,000 customers and businesses losing power and significant secondary impacts to the aviation sector due to the associated closure of Heathrow Airport. Power was quickly restored to impacted customers, and Heathrow restarted operations from late Friday 21 March. However, there was significant disruption at Heathrow Airport over the weekend of 22 and 23 March.

B.3 The Energy Secretary and Ofgem have therefore commissioned the independent National Energy System Operator (NESO), under condition C7.5 of the Electricity System Operator Licence, to review the incident, to identify lessons and recommendations for the prevention, and management of future power disruption events, and lessons for Great Britain's energy resilience more broadly.

Scope

B.4 NESO will identify lessons and good practice, regarding energy sector resilience, including both Distribution Network Operators, and Transmission System Operators, and, where relevant, those essential services and sites with a critical dependence on continued electricity supply, using an evidence-based approach. This review will not investigate the knock-on impacts to the transport sector as a result of the closure of Heathrow Airport, which will be covered in the Ruth Kelly review.

B.5 In particular, NESO will report on the following 3 pillars, in relation to this incident:

1. Resilience of energy infrastructure

a. Report on the root cause, other contributing factors, and sequence of events, of the outage at North Hyde electricity substation and subsequent supply disruption in the surrounding area (alongside the London Fire Brigade investigation).

b. Assess direct and secondary impacts of the event across GB electricity networks, electricity customers, and critical national infrastructure, including why it resulted in the closure of Heathrow.

c. Identify areas of good practice and where improvements are required for continued energy system resilience, considering relevant aspects such as asset management (including on or off-site mitigations), networks supporting the operation of critical national infrastructure (including internal networks that connect to the transmission or distribution systems) and future development of the electricity system;

2. Response and restoration of energy infrastructure

a. Consider what contingency planning had been undertaken in relation to the failure of electricity infrastructure, and assess whether the plans were enacted as planned and delivered as expected during the incident; and

b. Timeliness and effectiveness of the response to the incident, including communications with relevant stakeholders and the public.

3. Enhancing the resilience of critical infrastructure to energy disruption

a. Make recommendations for improving the resilience of essential services, including critical national infrastructure, to power disruption;

B.6 The review will focus on the resilience of Great Britain's energy system, given NESO's remit to provide independent advice on the security and resilience of the whole energy system. However, key findings and lessons will be shared with Northern Ireland as appropriate to ensure UK wide resilience to energy risks.

B.7 For certain aspects of the review, NESO may rely on information and evidence gathered from other sources; for example, London Fire Brigade, who continue to investigate the cause of the fire working close with electricity networks or other internal reviews currently being undertaken with regards to the outages.

B.8 A London Fire Brigade investigation will also explore the compliance of fire safety measures under the Regulatory Reform (Fire Safety) Order 2005 and any potential gaps in guidance or regulation.

B.9 During the review, NESO will draw on the expertise of the companies involved in managing and operating impacted electricity systems, operators of affected critical national infrastructure, regulators, government, and others. The review will not look more widely into airport operations and the impact on customers of the airport and aviation industry.

Deliverables

B.10 NESO will submit an initial report to the Secretary of State and Ofgem within six weeks, with an initial assessment of the data available at this stage of the review.

B.11 NESO will provide a final report to the Secretary of State and Ofgem by end of June 2025, which will include recommendations and lessons for the future and where possible, a proposed implementation plan. Key findings and recommendations of the review will be published by NESO.

C. Roles and responsibilities

C.1 **The following organisations have been identified as key stakeholders in this review and have been invited to contribute through information requests and/or fact-finding discussions.**

Organisation	Roles and responsibilities in this review
National Energy System Operator ("NESO")	NESO is the independent system operator and planner established under the Energy Act 2023. It has two relevant but distinct responsibilities in this review: • Planning Great Britain's electricity and gas systems, operating its electricity system, and making sure that Great Britain has the essential electricity it needs by ensuring supply meets demand every second of every day. NESO's System Operations directorate was actively involved in managing the system response to the incident. • Post-event analysis and assessment of an event that has detrimentally impacted the energy sector, engaging with relevant stakeholders to the extent required. In this case the review has been commissioned by the Secretary of State and Ofgem. More broadly, NESO is focused on ensuring a secure and affordable energy system for Great Britain, while also driving the transition to a clean energy future.
National Grid Electricity Transmission	The owner of transmission assets and responsible for the control of all equipment, maintenance, and incident response at the North Hyde 275kV substation. National Grid Electricity Transmission owns the North Hyde 66kV substation, with SSEN Distribution owning a number of assets within the site.
Scottish and Southern Electricity Network Distribution ("SSEN Distribution")	SSEN Distribution is the electricity Distribution Network Operator responsible for delivering power to customers across central southern England and the north of Scotland. It owns, maintains and controls the distribution network in the area and has a connection agreement with Heathrow Airport Limited. It operationally controls North Hyde 66kV, 22kV and 11kV substations.
UK Power Networks Services	UK Power Networks Services, the commercial arm of UK Power Networks, manages private energy networks and delivers national power infrastructure projects on a commercial basis. It has a service contract with Heathrow Airport Limited for maintaining the high voltage electricity distribution network at Heathrow Airport. UK Power Networks Services also owns and is responsible for the replacement of any high voltage network assets built before 2016.

Organisation	Roles and responsibilities in this review
Heathrow Airport Limited	Heathrow Airport is owned and run by Heathrow Airport Limited, which is owned by Heathrow Airport Holdings Limited. Heathrow Airport is the largest airport in Europe, connecting to over 230 destinations, serving over 82 million passengers a year and with over 26% of the UK's exports (by value) passing through the airport. Heathrow Airport Limited owns and controls its own private internal electrical distribution network to support its operations, supplied from three independent points on the SSEN Distribution's network. Heathrow Airport Limited is responsible for the control of all electricity networks at Heathrow Airport and directs UK Power Networks Services to carry out switching and maintenance on this network. Heathrow Airport Holdings Limited also owns and is responsible for the replacement of any high voltage network assets built after 2016. Heathrow Airport Limited commissioned its own review of the incident, the Kelly Review, which seeks to determine the chronology of events, identify the causes of the closure of the airport, evaluate the decisions leading to this, and to determine whether improvements are recommended for Heathrow Airport's resilience and preparedness for future power outage.
London Fire Brigade	London Fire Brigade is one of the emergency services for the Hayes area that responded to the incident. London Fire Brigade also worked closely with the Local Resilience Forum to manage local concerns. This included control of the site during the incident. London Fire Brigade is undertaking a forensic fire investigation of the fire at the North Hyde site with National Grid Electricity Transmission and transformer experts Doble, to establish details of its root cause and spread.
Metropolitan Police Service	Metropolitan Police Service is one of the emergency services for the Hayes area that responded to the incident. The Counter Terrorism Command of the Metropolitan Police Service (SO15) conducted initial investigative assessment of the fire.
Department for Energy Security and Net Zero	The Department for Energy Security and Net Zero is the government department responsible for enhancing UK energy security, protecting billpayers, supporting economic growth for the UK and generating and protecting jobs, and reducing the UK's emissions. The Secretary of State for Energy Security and Net Zero (the "Secretary of State"), working with Ofgem, has commissioned the National Energy System Operator, under condition C7.5 of the Electricity System Operator Licence, to carry out this independent review.

Organisation	Roles and responsibilities in this review
Office of Gas and Electricity Markets	The Office of Gas and Electricity Markets (“Ofgem”) is the non-ministerial government department that supports the Gas and Electricity Markets Authority (“GEMA” or the “Authority”). Ofgem’s principal objective is to protect the interests of existing and future consumers in relation to gas and electricity systems. The interests of such consumers are their interests taken as a whole, including their interests in the reduction of greenhouse gasses and in the security of the supply of gas and electricity to them. Ofgem, as the energy regulator for Great Britain, is responsible for working with government, industry, and consumer groups to deliver net-zero at the lowest cost to consumers. Ofgem plays a key role in deciding how investment is made on the network through the use of price controls.
Department for Transport	The Department for Transport is the government department responsible for working with agencies and partners to support the transport network. Amongst other responsibilities, it sets national aviation policy, working with airlines, airports, and the Civil Aviation Authority.
Civil Aviation Authority	The Civil Aviation Authority is the UK’s independent specialist aviation regulator, a public corporation, established by Parliament in 1972. Amongst other responsibilities, it regulates all certified UK airports to ensure they comply with relevant international and UK safety standards. It is also the economic regulator for Heathrow Airport.
Cabinet Office	The Cabinet Office’s purpose is ensuring that government works together to deliver for the people of the United Kingdom. Amongst other responsibilities, the Cabinet Office sets the overarching Critical National Infrastructure policy framework and governance for other government departments to ensure there is a consistent and coherent approach.
Local Resilience Forum – London Resilience	Local resilience forums (LRFs) are multi-agency partnerships made up of representatives from local public services, including the emergency services, local authorities, the NHS, the Environment Agency, and others. These agencies are known as Category 1 Responders, as defined by the Civil Contingencies Act. London Resilience coordinates institutions and communities to prevent, handle, recover and learn from disruption, and adapt to change; on behalf of the Mayor of London, Greater London Authority, local authorities and London Fire Brigade to ensure London survives and prospers.

D. Methodology and assurance

D.1 This section outlines NESO's approach to the incident review.

Investigation commissioned and Terms of Reference published

D.2 The Secretary of State and Ofgem have commissioned NESO, under condition C7.5 of the Electricity System Operator Licence, with reviewing the incident, identifying lessons and recommendations to prevent and manage future power disruption events, and drawing broader lessons for Great Britain's energy resilience.

Licence Condition	Obligation
Part B: Post-event and post-emergency analysis	C7.5. The licensee must, when requested by the Authority or the Secretary of State, provide post-event analysis and assessment in relation to an event that has detrimentally impacted, or could have detrimentally impacted, the licensee, gas and electricity consumers, or any licensed party operating across the National Transmission System, the National Electricity Transmission System, Distribution Network, Distribution Systems, Gas Interconnectors, Electricity Interconnectors, Electricity Generators, and embedded generators. C7.6. The licensee must, when requested by the Authority or Secretary of State, provide post-emergency analysis and assessment in relation to an emergency which has occurred on the National Electricity Transmission System and/or the National Transmission System. C7.7. The licensee must engage with the stakeholders which it determines to be relevant to the request under paragraphs C7.5 and C7.6 to the extent required.
Part F: Provision of reports and confidential information	C7.17. The licensee must seek the Authority's approval, prior to sharing, to provide appropriately redacted versions of the reports and assessments under Parts A, B, C, D and E to materially affected parties.

Figure 15: Authority to conduct review under Electricity System Operator Licence

D.3 The Terms of Reference for NESO's review were published on 28 March 2025 and are available on the Department for Energy and Net Zero's website. As per the Terms of Reference, the review was to focus on three main areas: the resilience of energy infrastructure, the response and restoration of energy infrastructure, and improving the resilience of critical infrastructure to energy disruption.

D.4 NESO was required to submit an initial report to the Secretary of State and Ofgem within 6 weeks, including an initial assessment of the data available at this stage of the review. This initial report was submitted on 6 May and published on 8 May 2025.

D.5 NESO was required to provide this final report to the Secretary of State and Ofgem by 30 June 2025. This final report needed to include recommendations and lessons for the future and, where possible, a proposed implementation plan.

NESO's responsibilities in relation to this review

D.6 NESO has two responsibilities for this review:

1. Delivering this review in line with the Terms of Reference and its licence responsibilities to provide post-event analysis.
2. Ensuring that NESO's System Operations directorate is treated equitably as a stakeholder participating in this review, given NESO's role in responding to the incident as the system operator for Great Britain's national electricity transmission system.

D.7 This review covered the sequence of events, root cause and contributing factors that led to the incident, and the immediate impacts on the wider energy system and electricity dependent Critical National Infrastructure. It also identified recommendations, lessons and good practice that could improve energy sector resilience.

D.8 This review did not investigate the subsequent impacts on the transport sector due to the closure of Heathrow Airport. Following the incident, Heathrow Airport Limited commissioned a review ("The Kelly Review") to outline the chronology of events, identify the causes of the closure of the airport, evaluate the decisions leading to this, and determine whether improvements are recommended for Heathrow Airport's resilience and preparedness for future power outage. The Kelly Review was published on 28 May 2025.

Process and methodology

Resourcing

D.9 To fulfil the commission from Department of Energy Security and Net Zero and Ofgem, NESO stood up an incident review team of circa 50 individuals from across the organisation with expertise in investigations, business continuity, networks, and operations. The review team was supported by access to an Independent Expert Advisory Panel. Further information on the panel's role and expertise is provided in 'Independent review and challenge'.

Information requests and validation

D.10 This review requested information from all relevant stakeholders. A list of parties who provided this review with information and evidence is provided at the end of the 'Methodology and assurance' chapter. Over 850 pieces of evidence were submitted to this review.

D.11 This review analysed the information received and identified thematic lines of enquiry. Where required, these have been followed up with approximately 12 fact finding discussions, predominantly held in person. Members of the review team have made site visits, including to the North Hyde substation site and Heathrow Airport, to understand better the nature and sequence of events.

D.12 The information received has been cross-checked and validated as far as practical to inform the outputs of this review. Each stakeholder has been given an opportunity to fact-check and validate all information sourced from or referencing them. Stakeholders have also been given the opportunity to redact sensitive information for security or commercial sensitivity reasons.

Information management and handling

D.13 This review logged all information received and gathered in a secure area, allocating a unique reference number to each document to ensure traceability throughout this review. All information has been carefully managed in line with NESO's data privacy and data security standards.

Methodology

Phase one: Sequence of events (the interim report)

D.14 The priority of phase one was establishing the timeline and sequence of events of the power outage, understanding and articulating the roles and responsibilities of the key stakeholders involved, and identifying areas of further investigation required to deliver the final report.

D.15 Phase one did not attempt to attribute causation but established a factual account of the sequence of events. This provided a baseline allowing further evidence and information to be put into the right context to ensure its significance to the events in question could be properly understood.

D.16 The outcome of phase one was the interim report, which was submitted to DESNZ and Ofgem on 6 May 2025, as per the Terms of Reference, and published on 8 May 2025.

Phase two: Analysis and recommendations (the final report)

D.17 The focus of phase two was on identifying and analysing the causes of the incident and any contributing factors to provide the basis of recommendations to improve energy resilience.

D.18 The primary root cause analysis methodology used for this review was the "5 Whys" approach. This review chose this methodology as it ensured analysis considered both the immediate cause of the incident, and the underlying causes that contributed to it, by continuing to ask 'why'.

D.19 The structure of the 'Analysis and recommendations' section of this report is the product of this methodology. It begins with the immediate cause of the incident (i.e., the failure of SGT3). It then explains step-by-step why this immediate cause resulted in subsequent de-energisation of different parts of the network. It ends with why this de-energisation resulted in Heathrow Airport's closure. For each step, the 5 Whys process was repeated in order to identify new underlying causes.

D.20 In taking this approach, this review developed a deep understanding of not just the incident, but the processes and systems underpinning the actions and decisions of key parties involved. This ultimately enabled this review to create more robust recommendations that seek to reduce the likelihood of recurrence and ensure that wider lessons can be learned.

Governance and assurance

D.21 Robust internal and external governance processes were established to ensure that the processes for information gathering, and report drafting have been rigorous and compliant with good practice. This review also established separate technical and legal assurance functions to provide guidance, review, and challenge. This governance process included the establishment of two new groups:

- **Project Delivery Board** - to provide strategic direction and a decision-making function in relation to planning the incident review, risks, and resourcing; and
- **Project Steering Committee** - to provide oversight of the full delivery, challenge and assurance processes to gain confidence that governance, risk management, and internal controls are functioning effectively, ensuring key risks are managed and compliance standards are met, and give final sign-off on key deliverables.

D.22 Ultimate oversight of the incident review has been provided by the NESO Board, as well as an Independent Expert Advisory Panel, composed of external cross-sector experts.

Conflicts of interest

D.23 NESO is committed to performing with the highest standards of ethical conduct and integrity. At the beginning of this review, employees involved were required to sign a confidentiality agreement and declare any actual or perceived conflict of interest pertaining to this review in accordance with NESO's Conflict of Interest and Disclosure Policy. Employees involved in this review were also exempted from responding to this review in their business-as-usual roles, ensuring adequate separation between the ring-fenced review team and other NESO employees.

D.24 In addition, a formal closed period for trading in National Grid plc and SSE plc shares ran for individuals involved in this review from 15 April 2025 and remained in place until the publication of the final report. During this period, employees were prohibited from engaging in any transactions involving National Grid plc and SSE plc shares, due to the sensitive information that employees were privy to as part of this review.

Legal assurance

D.25 NESO has worked with an external legal firm, Eversheds Sutherland, in relation to the incident review. The legal firm provided assurance advice in relation to NESO's governance systems for carrying out its review, reviewed process documents and question sets, and provided appropriate challenge to the incident review to ensure a robust process was adopted, outcomes were properly evidenced, and recommendations achieved.

Technical assurance

D.26 This report has been technically assured internally by NESO's functionally independent engineering assurance team. This team provided assurance over the rigour applied to the review process, in addition to verifying that the findings are substantiated in the report and can be traced back to an evidence source. Internal holistic assurance has been provided at Director level (led by the Chief Engineer and Director of Strategy & Policy).

D.27 A small team of external experts, led by a former Chief Operating Officer of a European Transmission System Operator, was onboarded to support the delivery of technical assurance.

Independent review and challenge

D.28 NESO brought together a panel of external cross-sector experts to act as an Independent Expert Advisory Panel for this review. The role of the panel was to provide independent scrutiny and challenge, and to assist NESO in completing this review robustly and thoroughly in accordance with the Terms of Reference. Panel members had expertise in areas such as airport operations, the management of electricity generation and distribution, the management of CNI, and major response management.

On the panel were:

Peter Emery - Chair, Greater Manchester Strategic Infrastructure Board, Non-Executive Chair or Director on Boards in the UK and Finland, Ex CEO of Electricity North West

Andy Lord – Commissioner, Transport for London and Non-Executive Director Defence, Equipment & Support, UK Ministry of Defence

Miriam Maes - Non-Executive Director on two Boards in France and Co-Chair of the Energy Transition Forum

Derek Provan, OBE - Non-Executive Director and ex-Chief Executive Officer of AGS Airports

D.29 For these purposes, panel members were acting as advisors to this review, and this review was permitted to share confidential information with panel members in accordance with its licence conditions. All panel members signed a confidentiality agreement setting out specific obligations with respect to information obtained as part of their role.

D.30 Panel members acted on a voluntary basis.

Sharing of report

D.31 In advance of any information being made public, this review shared relevant sections with stakeholders to enable them to fact-check and validate all information sourced from or referencing them. Stakeholders have also been given the opportunity to make representations regarding disclosure and/or redaction, and have been given fair notice of any actual criticisms or implied criticisms in this report. This review requested approval from Ofgem, prior to publication, to publish key findings and recommendations in the public domain with any appropriate redactions.

D.32 The interim report was shared with the Secretary of State and Ofgem on 6 May 2025. An embargoed copy was provided to contributing stakeholders at 21:00 on 7 May 2025, and the report was then published on NESO's external website at 07:00 on 8 May 2025.

D.33 The final report and confidential appendix were shared with the Secretary of State and Ofgem on 30 June 2025. This version of the report was not shared with contributing stakeholders. An embargoed copy of the final report was provided to contributing stakeholders at 21:00 on 1 July and published on NESO's external website at 06:59 on 2 July.

Information and evidence

D.34 The following table lists the stakeholders who provided information and evidence to this review.

Ark	Health and Safety Executive	National Protective Security Authority
Cabinet Office	Heathrow Airport Limited	NATS
Civil Aviation Authority	HM Treasury	Network Rail
CyrusOne	Independent Networks Association	Ofgem
Department for Business and Trade	London Fire Brigade	Scottish and Southern Electricity Networks Distribution
Department for Environment, Food and Rural Affairs	London Resilience	Scottish and Southern Electricity Networks Transmission
Department for Science, Innovation and Technology	Metropolitan Police Service	Scottish Power Energy Networks
Department for Transport	Ministry of Defence	Transport for London
Department of Energy Security and Net Zero	National Cyber Security Centre	UK Power Networks Services
Department of Health and Social Care	National Energy System Operator	UK Regulators Network
Energy Networks Association	National Grid Electricity Transmission	Virtus
GTC	National Preparedness Commission	

E. Key legislation, licences, and industry codes

E.1 This section provides a high-level summary of the main provisions in legislation, licences, and industry codes pertinent to resilience and restoration.

E.2 The transmission and distribution systems are designed against security and safety standards set out in legislation, licences and industry codes. Although the transmission and distribution systems are designed to have high levels of resilience, it is not possible to guarantee that there will be no supply interruptions. These legal documents do not provide any customer with a legal right to an uninterrupted supply.

E.3 The transmission and distribution systems operate on the principle of non-discrimination among customers; that is, no customer is entitled to a priority supply. An exception to this principle of non-discrimination may arise during a declared civil emergency, wherein the Secretary of State may invoke exceptional powers.

Legislation

The Electricity Act 1989

E.4 Under Section 9 of the Electricity Act 1989, holders of distribution and transmission licences have a duty to develop and maintain an efficient, coordinated and economical system of electricity distribution/transmission.

The Energy Act 2023

E.5 Energy Act 2023 makes provisions related to energy production and the security and regulation of the energy market. Part 5 of this act introduces the concept of the Independent System Operator and Planner (ISOP). NESO has been designated as the ISOP.

E.6 Section 163 of the Energy Act 2023 sets out a general duty on NESO, as the designated ISOP, to carry out its functions in the way that it considers is best calculated to promote: a) the net zero objective, b) the security of supply objective, and c) the efficiency and economy objective.

Licences

Electricity System Operator Licence and Transmission Licence

E.7 NESO and transmission licensees are required to plan and develop the transmission system in accordance with the National Electricity Transmission System Security and Quality Supply Standard (NETS SQSS), under Condition E7 of the National Electricity System Operator licences and conditions, as well as D3 and E16 of the Transmission Licence.

E.8 Under Condition E7 of the Electricity System Operator licence, the licensee must have a statement setting out the criteria by which system availability, security and service quality of the National Electricity Transmission System may be measured, and report against these criteria annually.

E.9 Under Condition B6.2 of the Electricity System Operator licence, the licensee must not unduly discriminate between any persons or class or classes of persons in the provision of Use of System, or in the carrying out of works for the purpose of connection to the National Electricity Transmission System.

E.10 Under condition D5 of the Transmission Licence, 'the licensee shall not unduly discriminate as between any persons or any class or classes of person or person or unduly prefer itself or any affiliate or related undertaking over any other person or persons or any class or classes of persons or persons'.

Distribution Licence

E.11 Under Distribution Licence Condition 19 (19.1) the licensees must not discriminate in carrying out works for the purposes of connection to the licensee's distribution system. There is also an obligation on the licensee (19.8) not to show undue preference to or unduly discriminate between any person, class or classes of persons when complying with the Distribution Code.

Industry Codes and Standards

E.12 Electricity transmission licensees are required by their licences to comply with the National Electricity Transmission System Security and Quality Supply Standard (NETS SQSS). NETS SQSS sets out the minimum standards that NESO is required to adhere to when planning and operating the National Electricity System (NETS).

E.13 In relation to the distribution network, the ENA Engineering Recommendation (EREC) P2, as contained in Annex 1 of the Distribution Code, stipulates the minimum demand to be restored within defined time periods following the loss of supplies in different outage scenarios.

E.14 The National Terms of Connection set out the terms and conditions that the network operator require to be accepted. These state in Section 3, paragraph 3.3 that 'the right to be (and remain) Connected does not include the right to be (and remain) energised', and in Section 3, Paragraph 4.4 that 'The Company does not guarantee that the supply of electricity will be free from transient variations in voltage and frequency or voltage pulses or harmonic frequencies, and the Customer must take its own protective measures if it requires a higher standard of supply.'

E.15 These standards are complemented by various licence conditions and industry codes, including the Electricity System Operator Licence, Gas System Planner Licence, and the Grid Code, which collectively establish the obligations and operational guidelines for maintaining system integrity and reliability.

National Electricity Transmission System (NETS) Security and Quality Supply Standard (SQSS)

E.16 The NETS SQSS sets the minimum requirements to which the transmission system must be designed and operated. It is possible to design above the minimum requirements where it can be economically justified.

E.17 The NETS SQSS is not intended to design a system where constraints or faults do not occur, but sets a design based on what is economically judged to be appropriate on balancing cost against probability or risk. The SQSS stipulates a level of security of supply by setting out the 'secured events' for which unacceptable conditions should not arise. When assessing demand connection capacity, this means that demand connections are planned and operated to stay within security criteria for the secured events of a fault outage (N-1) and planned outage followed by a fault outage (N-1-1). It is recognised that unsecured events may occur, and these could be more onerous than secured events. When unsecured events occur, their impact may lead to the operation of the system outside of normal parameters.

National Electricity Transmission System: Connection and Use of System Code

E.18 Parties have the right (and obligation) under Section 2 of the Connection and Use of System Code to be and remain connected and energised.

E.19 In case of demand customers, parties also have the right for power to be transported to the connection site. This is subject to other provisions in this code and Grid Code (which would include force majeure) and in the case of transport of power 'except to the extent (if any) that The Company is prevented from doing so by transmission constraints or by insufficiency of generation which, in either case, could not have been avoided by the exercise of Good Industry Practice by The Company'.

E.20 The rights under the Connection and Use of System Code itself are limited to liability in relation to breach of contract resulting in physical damage.

Distribution Network Operators: Distribution Code

E.21 One of the objectives of the Distribution Code is 'to permit the development, maintenance, and operation of an efficient, coordinated, and economical system for the distribution of electricity'. The Distribution Code acknowledges that there is a risk of disruption to supply from a distribution system and sets out the minimum periods for restoration.

E.22 Distribution companies are also subject to 'guaranteed standards of performance' (under The Electricity (Standards of Performance) Regulations 2015 (as updated) which sets out compensation payable to customers in the event of disruption to supply for certain events.

Distribution Network Operators: ENA Engineering Recommendation P2

E.23 ENA Engineering Recommendation (EREC) P2, published by the Energy Networks Association, has a similar function to the SQSS for electricity distribution networks. EREC P2 is listed in Annex 1 of the Distribution Code and forms part of the Distribution Code. Distribution network operators are required to comply with the Distribution Code under Condition 20.1 of the distribution licence.

E.24 The distribution networks in England and Wales operate at 132kV and below. P2 stipulates minimum demand to be restored within defined periods of time in different outage scenarios. Standard Condition 24 of the Electricity Distribution Licence requires licensees to plan their system with a standard not less than P2.

E.25 North Hyde 275kV substation falls under the class of supply D, for demand of over 60MW and up to 300MW, in EREC P2. These state that for a first circuit outage, demand served by the substation minus up to 20MW should be restored immediately, and all demand should be restored within 3 hours. For a second circuit outage, for demands greater than 100MW, the smaller of either total demand minus 100MW or one third of total demand should be restored within 3 hours. There is no time limit to restore all demand from a second circuit outage.

E.26 The recommendation states this is based on the assumption that the time for restoration of demand after a second circuit outage will be minimised by the scheduling and control of planned outages, and that consideration will be given to the use of rota load shedding to reduce the effect of prolonged outages on consumers.

Electricity Safety, Quality and Continuity Regulations 2002

E.27 The following regulations of the Electricity Safety, Quality and Continuity Regulations 2002 (ESQCR) are relevant to the incident at the North Hyde site.

E.28 Regulation 11 of ESQCR specifically relates to safety at electricity substations, and, in relation to fire management, Regulation 11(d) states that owners/operators of substations are required to 'take all reasonable precautions to minimise the risk of fire associated with the equipment.' ESQCR guidance issued by the Department of Trade and Industry in 2002 provides additional details on what duty holders are required to do in order to comply with regulation 11(d).

E.29 Regulation 31 of ESQCR requires duty holders to notify the Secretary of State where there is a fire attributable to the generating, transforming, control or carrying of energy on the duty holder's network.

E.30 Regulation 32 of ESQCR requires duty holders to notify the Secretary of State where there is an interruption of supply to:

(a) any demand of 20 megawatts or more, for a period of three minutes or longer;

(b) any demand of 5 megawatts or more, for a period of one hour or longer; or

(c) 5,000 or more consumers' installations for a period of one hour or longer.

Glossary

Glossary

Autoclose scheme
A system which automatically switches replacement equipment into service when needed, for example when equipment is on 'hot standby'.

Busbars
A busbar is a metallic strip used to conduct electricity. It is the central point that connects multiple circuits within a substation.

Circuits
Circuits are paths for transmitting electric current between generation and demand. A complete circuit requires an energy source – such as a battery or electricity generator – a source of demand for using that energy, and the wires or other conductive material that connects the two.

Configuration
Configuration is the description of how energy network components are connected together, including where electricity is supplied from, and what it in turn supplies.

Re-configuration refers to changing how the network is connected together.

Critical National Infrastructure (CNI)
The critical elements of infrastructure (namely assets, facilities, systems, networks or processes and the essential workers that operate and facilitate them), the loss or compromise of which could result in major detrimental impact on the availability, integrity, or delivery of essential services and/or significant impact on national security, national defence, or the functioning of the state.

Distribution network
The network of overhead lines, pylons, poles, underground cables and substations that connect electricity to and from the transmission network and generators to electricity consumers. The distribution networks in England and Wales operate at 132kV and below.

Electrical arcing
Electrical arcing is a continuous, high-density electric current between two separated conductors in a gas or vapour with a relatively high potential difference, or voltage, across the conductors. A high potential difference strips electrons, leading to ionization which produces a conducting path, and the formation of an arc.

Electricity substation
Electricity substations are where overhead lines, underground cables, transformers, and other electrical equipment are connected together creating the network required to connect electricity generation and the end customer.

Essential function
The high-level services that a CNI sector or sub-sector provide to the UK. For the energy sector for example, this includes both the generation of electricity and the transmission of electricity.

Flashover
A flashover is the near-simultaneous ignition of gasses created by the heating of combustible materials to their ignition point – thick smoke is an indication of this risk.

Hot standby
Used to describe the status of an active and connected part of a system that is acting as a backup and can take over rapidly to provide continuity of operations.

Interceptor
An interceptor is used to collect water runoff which may contain pollutants such as oil. Typically an underground tank, interceptors allow for the separation, treatment or removal of pollutants before the water enters the local drainage system and the wider environment.

Interconnector cables
In the context of supergrid transformers and substations, interconnector cables connect different substations together.

Load
The electrical power flowing through an electrical asset or system. If the system or part of the system cannot supply that demand, it is described as off-loaded.

Leased network
Parts of private internal electrical distribution networks that are owned by one entity but leased through contractual arrangements to another to operate and maintain.

Online continuous condition monitoring solutions
Refers to systems and technologies used to monitor the condition of equipment or machinery continuously. These solutions are designed to provide rapid indication of any changes or anomalies in performance (more rapid than periodic sampling), which can quickly prompt the need for action including removing equipment from service prior to maintenance or repair.

Power restoration
Restoration refers to the process of restarting the flow of energy following an outage. In the context of restoring power to a substation, this may be referred to as re-energisation.

Priority Service Register
The Priority Service Register is a free service for customers who may be vulnerable in the event of power outages, for example due to medical conditions.

Private internal electrical distribution network
A private internal electrical distribution network is the infrastructure that distributes energy to a private site, such as Heathrow Airport. These networks are operated by Private Network Operators under an exemption from holding a distribution licence regulated by Ofgem.

Radio Frequency Interference (RFI)
These are tests on transformers that are used to detect and identify internal discharges, which can be a sign of faults. These tests measure the electromagnetic radiation generated by these discharges using a radio frequency spectrum analyser and different types of antennas.

RIIO-T2
RIIO-T2 is second price control using the RIIO (Revenue = Incentives + Innovations + Outputs) mechanism for electricity transmission networks and covers the five years from 2021 to 2026. Price control is the term given to the process that a regulator, in this case Ofgem, uses to determine and set the revenue that transmission owners are able to recover to fund the work their licence obliges them to do.

A "price control submission" is a piece of information and analysis which explains why work is required in a certain area, what volume is likely to be needed and the price. As such it is a key building block in determining how much revenue is needed to run a transmission network.

SQSS
The Security and Quality of Supply Standard (SQSS) sets out the minimum standards for planning and operating the National Electricity Transmission System (NETS).

Supergrid transformer
At substations, voltages are stepped up or down through electrical devices called supergrid transformers.

Supply cable
The supply cable of a supergrid transformer is the high voltage cable that carries electricity to the supergrid transformer.

Switching
The process of opening and closing switches and putting assets in or out of service, either automatically, for example to protect assets in the event of a fault, or manually to reconfigure the network by the party responsible for the control of that part of the network.

Tap changer
A tap changer is a device that is used to adjust the output voltage of a transformer in order to keep substation voltages within acceptable ranges as the demand varies throughout the day. These adjustments can be made manually or automatically by voltage control systems, and the tap changers are filled with insulating oil (or sometimes gas) which acts to quench arcs that are temporarily formed when the tap changer changes connections.

Thermovision
A non-intrusive test that uses infrared cameras to detect heat emitted by electrical components, which can provide an indication of an underlying problem or fault.

Transformer bushing

A transformer bushing is a structure which provides an insulated pathway for current to flow safely in and out of a transformer. They are typically made of materials like porcelain, resin, or oil-impregnated paper, chosen for their insulating and mechanical properties.

Transmission network

The network of overhead lines, pylons, underground cables, and substations that transport electricity over long distances. The transmission network in England and Wales operates at 275kV (kilovolts) and above.

Trip

Electrical circuits are fitted with circuit breakers that are designed to react when there is excess current on a circuit posing a fire hazard. The excess current activates a trip coil, which is an electromagnetic device that is energised when a fault on the high voltage circuit is detected. Once energised, the trip coil's magnetic field closes electrical contacts in the control circuit of the circuit breaker, causing the circuit breaker to open and remove the faulty equipment from the system. As a result, electricity ceases to flow across the circuit.

National Energy System Operator
Faraday House
Warwick Technology Park
Gallows Hill
Warwick, CV34 6DA

NESO
National Energy
System Operator