The voice of the energy industry

On behalf of the Energy Emergencies Executive Committee (E3C)

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FAO: GB Generators and energy market participants

Great Britain power system disruption on 9 August 2019: preliminary lessons learnt for generators

As generator representative of the Energy Emergencies Executive Committee (E3C), Energy UK was tasked with fulfilling *Action 1: The E3C, in collaboration with the relevant trade associations and generators, to disseminate lessons learnt to the wider electricity connected generation community* on behalf of the E3C and its final report into the GB power system disruption on 9 August 2019 (available here).

Attached to this letter is a summary of the preliminary lessons learnt from the events of the 9 August 2019, and steps that generators should take from these experiences. It should be noted that at this time not all investigations have been complete, and that there will likely be further lessons learnt to follow in the future. The E3C will share these with stakeholders when available.

Please could you disseminate these lessons learnt to all relevant departments and contacts within your organisation. If you have any questions, please feel free to contact me.

Yours sincerely,

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Great Britain power system disruption on 9 August 2019: preliminary lessons learnt for generators

1.1. Document purpose

This document has been produced on behalf of the Energy Emergencies Executive Committee (E3C) and in line with actions arising from the E3C's final report on the GB power system disruption that occurred on 9 August 2019[1]. It aims to provide all relevant GB electricity generators, connected at transmission and distribution level, with an understanding of the preliminary reasons identified for the disconnection of generation that resulted in a frequency deviation, and the consequential necessity to trigger the automatic first stage of Low Frequency Demand Disconnection (LFDD). This document also provides an overview of the lessons learnt by these generators, and potential actions and considerations for similar parties to help mitigate such events in the future. As further investigations develop and conclude, further information will be disseminated when available.

1.2. Background

a) On Friday, 9 August 2019 a lightning strike on the electricity transmission network at Eaton Socon-Wymondley caused a voltage fluctuation that was ultimately cleared within 80ms.
b) This voltage fluctuation initiated a trip of 150MW of distributed generation (also known as "embedded generation") due to Vector Shift Protection settings, and the rapid de-loading of Hornsea-1 from 799MW to 62MW – this was unexpected.
c) Shortly after, the steam unit at Little Barford automatically disconnected from the transmission system due to a discrepancy identified on the speed sensors.
d) Due to this loss of generation, the frequency of the electricity system rapidly declined at a rate of 0.125Hz/s, causing a further 350-430MW of embedded generation to trip due to legacy Distribution Code requirements.
e) Following this, Frequency response was activated arresting the frequency decline at 49.1Hz and recovering to 49.2Hz before one of the gas turbines (210MW) at Little Barford was shut down due to an unsafe build-up of steam pressure. This resulted in the frequency declining once again to 49Hz, where some embedded generation tripped due to frequency protection settings activated, causing the system frequency to continue to fall to 48.8Hz, activating Stage 1 of LFDD.
f) Plant staff at Little Barford then manually tripped the second gas turbine due to safety concerns.

The events of the evening saw between 2,678 and 2,878MW loss of generation in total, 1,378MW from the transmission network and between 1300MW to 1500MW from the distribution network, including generation disconnected through the process of Stage 1 LFDD.

1.3. Transmission Connected Generation

- Hornsea-1

Hornsea-1 is a 1200MW offshore windfarm consisting of three phases, each 400MW, owned and operated by Ørsted. At the time of the event on the 9 August, Hornsea-1 was in the process of

[1] https://www.gov.uk/government/publications/great-britain-power-system-disruption-review

demonstrating compliance with the Grid Code and satisfying its commissioning requirements of the Connection and Use of System Code (CUSC). Hornsea-1 is still ongoing construction offshore.

At 16:52 on 9 August, Hornsea-1 unexpectedly rapidly de-loaded from 799MW to 62MW due to identification of an unusual event, causing a 'weak' electricity system and voltage disturbance. This unusual event was found to be caused by a circuit trip on the 400kV electricity transmission network. This trip was the automatic function of the electricity transmission network protecting itself from the short circuit caused by the lighting strike at Eaton Socon-Wymondley.

To compensate for this reduction in voltage on the electricity system, Hornsea-1's reactive compensation control system initially injected reactive power, before oscillations occurred, causing it to absorb reactive power, and then inject reactive power again repeatedly. As a consequence, Hornsea-1 reduced active power from 799MW to 400MW before returning to 799MW. These rapid changes between injection and absorption of reactive power caused the voltage in the cable collection of Hornsea-1 to reduce to 20kV (target voltage is 34kV) resulting in two of the three Hornsea-1 units to reduce output to 0MW as part of its overcurrent protection settings.

Ørsted has acknowledged that although these conditions experienced were unusual, it was expected that Hornsea-1 would withstand such an event and remain in operation. Oscillations between reactive power injection and absorption are an inherent feature of electrical power systems and are not usually problematic when adequately damped. Prior to the event of the 9 August, Hornsea-1 had been fully modelled and physically tested, demonstrating its compliance with the Grid Code, and it had not exhibited any indications that it would respond to a fault of this kind on the electricity network in the way that it did.

On 10 August 2019, the manufacturer of the offshore assets installed a software update to the control systems, improving the damping of system oscillations such as those experienced over the 9 August incident. This software update also acted to improve response to system disturbances in weak system conditions. This software update mitigates the observed behaviour of Hornsea-1 stabilising the control system to withstand future grid disturbances in line with the Grid Code and the station's connection agreement requirements.

- Lessons Learnt or Actions for generators from Hornsea-1

It is advised that individual owners/operators of relevant generators are to review control systems and the performance of reactive power oscillation damping to ensure compliance with all relevant industry codes and licenses.

- Little Barford

Little Barford is a 740MW Combined Cycle Gas Turbine (CCGT) owned and operated by RWE. This station can be defined as two gas turbines, feeding two boilers, producing steam to turn a single steam turbine. Following the lightning strike on the electricity system at Eaton Socon-Wymondley, the steam turbine tripped within 1 second, followed by the first gas turbine tripping around 1 minute later, and the second gas turbine being manually shut down around 30 seconds after that. In total, this brought about a total loss of 641MW. RWE's investigation in to the cause of this loss is still ongoing, but a summary of the current understanding is provided below.

It has been identified that the steam turbine trip was caused by a discrepancy among three independent speed sensors on the turbine, exceeding the tolerance allowed on the control system and instigating an automatic shutdown following the point of the transmission system fault clearance. The root cause has

not, as yet, been ascertained, however, a preliminary view has been established that the trip and the speed sensors discrepancy was caused by the transmission network fault consequent of the lightning strike at Eaton Socon-Wymondley. RWE has since increased the allowable tolerance in discrepancy between the speed sensors to maintain necessary protection, enhancing the stations ability to not trip or disconnect in the future under similar scenarios.

Following the steam turbine trip, steam was diverted around the turbine to allow the station to run in Open-Cycle Gas Turbine mode, however, the pressure of the steam was measured and deemed too high to continue operation and led to the gas turbine trip. This process is onerous on the plant involved. Safety is of paramount importance when dealing the energy and heat involved and many systems are configured to monitor this bypass process. After the 9 August event RWE has reviewed its monitoring systems and has achieved a range of settings that will still ensure safety whilst providing a more resilient and tolerant bypass routine against tripping of the gas turbines.

RWE's investigation has so far found that all Uninterruptable Power Supply (UPS) systems on site functioned correctly to enable supply to plant equipment, and Original Equipment Managers (OEM) have confirmed that the units functioned as expected, it is, therefore, unlikely that the UPS contributed to the subsequent trip. However, as the full root cause of the speed sensor readings has not been attained, RWE cannot fully discount the possibility of the UPS having had some impact, even if the likelihood is very low. During an outage in September 2019, RWE requested that the OEM undertook resilience testing to reaffirm the functionality of the system and cross reference these results to the previously undertaken manufacturing tests, the results showed that the UPS functioned as designed.

- Lessons Learnt or Actions for generators from Little Barford

It is advised that all owners/operators of relevant generators should verifying turbine speed monitoring logic to establish its suitability and associated parameters settings. This may be a common issue among CCGT's.

It is advised that all owners/operators of relevant generators should review the pressure limits of the systems and the tolerances of their steam bypass protections, to ensure continued generation, whilst maintaining safety.

It is advised that all owners/operators of relevant generators should review its UPS systems on site to ensure correct and expected functioning, as this cannot be discounted as contributing to the disconnections at Little Barford at this time.

1.4. Distribution Connected Generation (embedded generation)

- Embedded generation

Over the event of 9 August, between 1,300MW and 1,500MW of embedded generation tripped or disconnected from the electricity system. This generation loss can be generally attributed to four known categories (Vector Shift, Rate of Change of Frequency (RoCoF) protection settings, disconnection at the 49Hz threshold, and Stage 1 - LFDD). Beyond these, an additional 100MW of generation was lost for an unknown reason at present. It has been deemed that a large proportion of the embedded generation that disconnected or tripped from the electricity system did so due to over-sensitive protection settings and these should be reviewed immediately.

An initial 150MW was tripped due to Vector Shift immediately following the lighting strike at Eaton Socon-Wymondley. Under the circumstances of 9 August event, Ofgem acknowledges in its report that the Vector Shift protection setting is no longer permitted for embedded generators as of 1 February 2018.

A further generation loss of between 350MW to 430MW was found to have been due to RoCoF protection settings. It is understood that a portion of this generation greater than 5MW capacity de-loaded from the system erroneously, due to RoCoF protection settings that had not been changed following 2014 Distribution Code modifications.

Following the frequency falling to the 49Hz threshold, an estimated 200MW of generation tripped off of the system unexpectedly. This lower frequency threshold sensitivity for embedded generators was enhanced in the Distribution Code from August 2010 for generators with a capacity greater than 5MW to 47Hz.

A further 100MW of embedded generation was lost, attributed to either de-loading or tripping. The cause for this loss is unknown at present.

Once the frequency fall hit 48.8Hz, Stage 1 of Low Frequency Demand Disconnection was activated by DNO's where up to 5% of total demand is disconnected. It has been found that this had the consequence of 550MW of further generation being disconnected from the electricity system.
The recent Accelerated Loss of Mains Change Programme (ALoMCP) is an initiative launched in 2019[2], alongside the Distribution Code requirement that all owners of generation installed before February 2018, and where the generation equipment is not type-tested, are to comply with new setting requirements for the interface protection in accordance with Engineering Recommendation G59. Owners of relevant generation must comply with the Distribution Code, and have until 31 August 2022 to comply with these modified interface protection requirements. To incentivise the ALoMCP National Grid ESO and DNO's have set out a payment scheme for relevant generators.

Registration for ALoMCP and further information can be found here.

It is the responsibility of all generators to ensure compliance with the relevant industry codes. If an embedded generator is unsure of its obligations, they should contact their relevant DNO, the Electricity Networks Association (or relevant code administrator), and take their own technical and/or legal advice.

- Lessons Learnt or Actions for embedded generators

It is advised that individual owners/operators of embedded generation review protection settings in line with all relevant code and licence obligations updates and modifications. It is the responsibility of all generators to ensure their compliance with the relevant industry codes and regulations. Settings to be reviewed should be inclusive of, but not necessarily limited to:

- Ensuring that Under Frequency protection settings are in line with Distribution Code Requirements, and any future modifications are complied with.
- Ensuring that RoCoF relay settings are set in line with current Distribution Code Requirements, and any future modifications are complied with.

[2] http://www.energynetworks.org/electricity/engineering/accelerated-loss-of-mains-change-programme.html

- Removing any Vector Shift Protection, and replace with RoCoF protection (if Loss of Mains protection is required)[3].
- Removing or deactivating Loss of Mains protection that is unnecessary.

It is advised that individual owners/operators of embedded generation review their suitability and consider suitability for the Accelerated Loss of Mains Protection Settings support scheme. Further information can be sought through the Energy Networks Association or your relevant DNO.

It is advised that individual owners/operators of embedded generation discuss with their relevant DNO its arrangements for LFDD to review the suitability of generation disconnection through this process.

[3] https://www.ofgem.gov.uk/publications-and-updates/distribution-code-dc0079-frequency-changes-during-large-disturbances-and-their-impact-total-system-phase-4-dcrp1808