Meeting Date: 12 March 2020

Overview of the 19 August 2019 power blackout in England and Wales

Security and Reliability Council

Note: This paper has been prepared for the purpose of the Security and Reliability Council (SRC). Content should not be interpreted as representing the views or policy of the Electricity Authority.

Overview of the 19 August 2019 power blackout in England and Wales

1. Lessons from the event

1.1. The SRC provides advice on reliability of supply issues in New Zealand. To that end, the SRC requested the (New Zealand) system operator to “present an overview” of the 19 August 2019 power blackout in England and Wales. This is recorded in action item #3 for this meeting.

1.2. The system operator conducted its review and provided the attached overview. As intended, the system operator has undertaken its review with the lens of what lessons might apply here. The overview identifies four lessons for New Zealand. The SRC secretariat agrees that all four are valid lessons from the event.

1.3. In addition to those four lessons, the secretariat considers that performance of the generators involved may point to two further generic lessons.

1.4. The tripping of the Hornsea offshore windfarm provides a lesson that should already be familiar in New Zealand. Hornsea tripped due to “unexpected windfarm control system response.”[1] New Zealand has already encountered unexpected control system behaviour in at least several incidents.

a) A windfarm in the Wellington area failed to ride-through a system disturbance due to unexpected control system response. It was subsequently treated as a secondary risk by the system operator, resulting in additional reserves being procured to cover that risk until such time as the wind turbine manufacturer remedied the underlying issue.

b) Manapouri power station ramped down by 350 MW on 22 July 2016 when its SCADA system lost its setpoint instructions following unexpected behaviour during SCADA system maintenance work onsite.

c) A logic fault in the protection system of AC transmission assets at Benmore caused an HVDC trip on 12 November 2013 with the loss of 401 MW of load in the North Island.

1.5. The tripping of generation at Little Barford power station highlights the importance of generators and system operators understanding operational post-event dependencies among co-located assets. The initial trip of the steam turbine at Little Barford “was caused by a discrepancy between the measurements from three speed signals.”[2] The same section of the National Grid’s technical report goes on to quote the generation owner that:

> “…for reasons presently unknown, after approximately 1 minute [after the steam turbine tripped] the first gas turbine tripped due to a high-pressure excursion in the steam bypass system. This trip occurred automatically and

[1] Page two of the system operator’s report (Appendix A). Section 4.2.1 of National Grid’s technical report quotes the generation owner that “The wind turbine settings were standard settings from the manufacturer. During the incident, the turbine controllers reacted incorrectly due to an insufficiently damped electrical resonance in the subsynchronous frequency range, so that the local Hornsea voltage dropped and the turbines shut themselves down.”

[2] Section 4.2.2 of National Grid’s technical report.

> shut the gas turbine (GT1A) down. The second gas turbine (GT1B) was manually tripped by [our] operational staff in response to high steam pressures around 30 seconds later."

1.6. The secretariat is not aware of any generation assets in New Zealand to which similar specific aspects would apply. Co-generation, by definition, has dependencies on an industrial production process and this carries some inherent complexities. Risk to the power system from these sites tends to be low, as disruption of the industrial process trips more load than the loss of any onsite generation. However, the 5 October 2014 cable trench fire at the Penrose substation illustrated that smoke causes arcing and corona discharge in a switchyard. In that event, the neighbouring 220 kV switchyard was de-energised to enable firefighter access.

1.7. In the secretariat's cover paper to a 28 March 2017 agenda item, it stated:

> "There are venues for companies to share lessons relating to health and safety matters. StayLive's 'Process Safety Industry Group' subgroup enables its members to learn from each other and to improve safety outcomes. The SRC secretariat is not aware of any equivalent forum for either the operational lessons in the electricity industry, or risk management generically. SRC members may wish to consider whether such a function is desirable and would be of net benefit."

1.8. The SRC subsequently advised the Authority Board that "…the Authority should explore with the [Electricity] Engineers' Association whether they may be a suitable venue for sharing lessons from operational events."[3] The secretariat is not aware of any subsequent relevant correspondence from the Authority to the Electricity Engineers' Association.

2. Questions for the SRC to consider

2.1 The SRC may wish to consider the following questions.

Q1. Are SRC members aware of any venues for electricity asset owners to share operational lessons from incidents and near misses?

Q2. What further information, if any, does the SRC wish to have provided to it by the secretariat?

Q3. What advice, if any, does the SRC wish to provide to the Authority?

[3] 16 May 2017 SRC letter of advice to the Chair of the Electricity Authority.

INTERNATIONAL POWER SYSTEM EVENT REVIEW

UK Low Frequency Demand Disconnection event on 9 August 2019

System operator review and identification of lessons for New Zealand power system operation

1. Purpose

The purpose of this paper is to inform the Security and Reliability Council of lessons for operation of the New Zealand power system following a review of a recent major power system event in the United Kingdom (the UK event). Our review is part of ongoing activity in our role as system operator, where we actively monitor and review large systems events to inform development of our own operating practices for managing high impact–low probability events, and impacts from new technologies.

This paper summarises the essential elements of the system operator's full review report which will be published on Transpower's website in March.

2. Context and summary

On 9 August 2019, a major power system event occurred in the UK resulting in the activation of its Low Frequency Demand Disconnection (LFDD) scheme. This disconnected approximately 1 GW of demand with an associated interruption in electricity supply to over one million consumers.

National Grid as the Electricity System Operator (ESO) in the UK published *its technical report* assessing this event on 9 September 2019. The Office of Gas and Electricity Market (Ofgem), subsequently published its report on the 3 January 2020 detailing *its investigation* into this event.

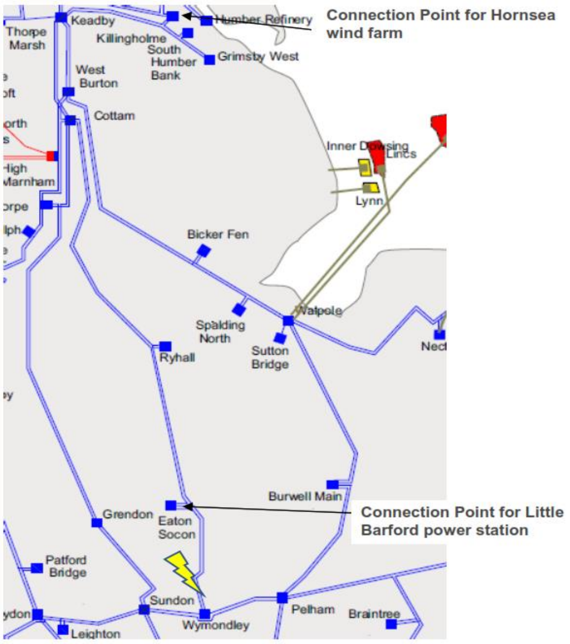
Our review is based on the technical report and the recommendations made by National Grid with consideration of observations made in Ofgem's investigation.

The balance of this paper describes the event and our observations, and sets out the lessons and actions for New Zealand to consider.

3. Event summary

On 9 August 2019, the alternating current (AC) transmission circuit connecting Eaton Socon and Wymondely Main was tripped by a single lightning strike. Coincidental with the lighting strike was the expected loss of a small amount of embedded generation. This was followed by unexpected reduction of generation output from the Hornsea offshore windfarm, and the tripping of generating units at Little Barford power station. The accumulative loss of generation caused a rapid fall in frequency, breaching the normal range of operation, and a further disconnection of embedded generation[1]. These events activated the LFDD scheme in order to preserve the system and resulted in the interruption of approximately 1 GW of electricity supply to consumers.

[1] Defined by Ofgem, as electricity generation in the UK which is connected to the distribution network rather than to the high voltage Transmission network. Embedded generation is typically smaller generation such as Combined Heat and Power or renewable generation (small hydro, wind or solar power).



Event sequence:

- Eaton Socon–Wymondley Main circuit
  - *initially tripped by lightning*
- Embedded generation (-150 MW)
  - *tripped on loss of mains protection triggered by vector-shift protection*
- Hornsea offshore windfarm (-737 MW)
  - *de-loaded due to unexpected windfarm control system response*
- Little Barford power station (-641 MW)
  - *steam turbine tripped – cause unknown*
  - *2x gas turbines tripped due to high-pressure excursion protection*
- Embedded generation (-350 to -500 MW)
  - *tripped on loss of mains protection triggered by rate of change of frequency protection*
- Activation of LFDD scheme (+931 MW)
  - *disconnection of electricity supply*

Figure 1 – UK event summary and geographical layout of the transmission circuit.

4. Post–event observations

The scale of generation loss during the UK event was in excess of the 'normal infeed loss' (credible contingency) and reserve dispatch. It caused frequency to rapidly fall and activate the first stage of the LFDD scheme which disconnected approximately 5 per cent of the UK's demand. The design and operation of frequency response products and demand shedding scheme worked well. However, when frequency went outside of the normal operating range and fell below 49 Hz, this had unintended impact on other critical infrastructure and services.

From a transmission and power system perspective, the existing systems and processes adopted by National Grid operated within the required timeframe and responded well to the UK event; system frequency recovered to 50 Hz within 5 minutes and the system was restored within 45 minutes. However, what has been highlighted by this event is a number of other observed impacts, such as frequency ride-through capability of trains, resilience of hospital equipment, incorrect load classification, unexpected outcomes from a windfarm control system and inadequate generator ride-though capability. Although train and hospital equipment frequency or voltage ride-through capability are not directly related to the activation of the LFDD scheme, the inherent issues and risks were exacerbated and brought to the surface during this event.

The most notable and unintended consequence of this UK event was the disruption to the rail network. Although, the electricity supply to the rail network was not interrupted, 60 passenger trains operating on AC power supply suffered an internal protective shutdown and permanent lockup. This occurred when the frequency fell below 49 Hz, which was above the technical stated continuous operating frequency standard (48.5 Hz). Approximately half the train fleet were able to be restarted by the driver on-site, but the remainder required technicians to initiate a laptop reset. London's St Pancras and King's Cross train stations were closed for several hours as a result of the train stoppages which affected thousands of commuters during the Friday rush hour.

5. Lessons for New Zealand

The review of this major power system event in the UK has provided several lessons and considerations to aid system operations in New Zealand.

Based on our review of the National Grid and Ofgem investigations, we have identified from their recommendations the following important issues that may have implications for New Zealand, and what actions are required:

- **System resilience standard and embedded generation (National Grid's recommendations 1 and 3)**: The current penetration level of embedded generation, such as residential solar and wind systems, are low in New Zealand by comparison to the UK. However, the UK event has again highlighted the need to ensure the collective response of any embedded generation to system disturbances is considered and accounted for when evaluating and managing system risk. It has also highlighted the issue that if adopted performance standards for embedded generation are not well aligned with overall system operation, then it is very difficult and time consuming to retrospectively correct any underperformance.

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  As the system operator, through our credible event review process[2], we will continue to engage with the Electricity Authority (Authority) and industry participants in the identification and classification of future risks to the security of the power system; This includes risks associated with embedded generation behavior.

  The system operator will also continue work with and support the Authority and distributors in lobbying WorkSafe to update the Wiring Regulations to consider the latest versions of inverter connection standards which have better fault ride-through requirements. Incorporation of these standards will help reduce the likelihood of large amounts of embedded generation tripping during a frequency event. Otherwise the need would most likely be mitigated via the procurement of additional reserves.

- **Rail service and critical infrastructure (National Grid's recommendation 2)**: Although not directly within the remit of the electricity industry, the UK event has highlighted the need to ensure critical services and infrastructure understand the impact of the range of disturbances which may occur on the power system they are connected to.

  In our role as system operator, we will bring to the attention of New Zealand electric train operators[3] (as direct connects) and distribution companies the lessons from this event on frequency and voltage ride-through capability for their consideration.

- **Communications (National Grid's recommendation 4)**: The UK event highlighted the importance and increasing expectation of timely communication with both communities and stakeholders. Communication should include a description of what has occurred to create a power disruption and when power will be restored.

  In our role of system operator, we will continue to work with the grid owner, industry participants and other stakeholders on improving our ability to provide coordinated situational awareness during power system events, including restoration times.

We also identified one further aspect not covered directly by National Grid's recommendations for consideration:

- **Low frequency demand shedding issues**: Although the UK LFDD scheme successfully arrested the fall in frequency, the reduction in demand was less than expected. The scheme also disconnected a number of hospitals and water treatment facilities which further compounded the disruption to consumers.

[2] The credible event review process identifies key asset risks and reviews how those risks are best managed considering consequences and cost. Information relating to event categorisation is published on the Transpower system operator website: https://www.transpower.co.nz/system-operator/operational-information/event-categorisation

[3] KiwiRail and Auckland Transport

In New Zealand we rely on automatic underfrequency load shedding (AUFLS) as the last line of defense for 'extended contingent' and 'other' events. The UK event has highlighted the need to actively monitor and model the amount and type of load armed at any given time for AUFLS.

In our role as system operator, we will continue to undertake post–event analysis of AUFLS events to assess and adjust scheme performance. We will also work with and support the Authority and AUFLS providers with progressing the Extended Reserves project[4]. This will deliver greater assurance of AUFLS performance and eventually transition to an enhanced four block scheme providing greater flexibility and resilience.

[4] The focus of the Extended Reserves project was refined by the Authority in October 2019. More details can be found here: https://www.ea.govt.nz/development/work-programme/risk-management/extended-reserve/development/extended-reserve-project-refocused/