What do the recent blackouts tell us about the current state of decarbonised power systems?

Janusz Bialek

Professor of Power and Energy Systems

Newcastle University and Skoltech

Newcastle University

Skoltech

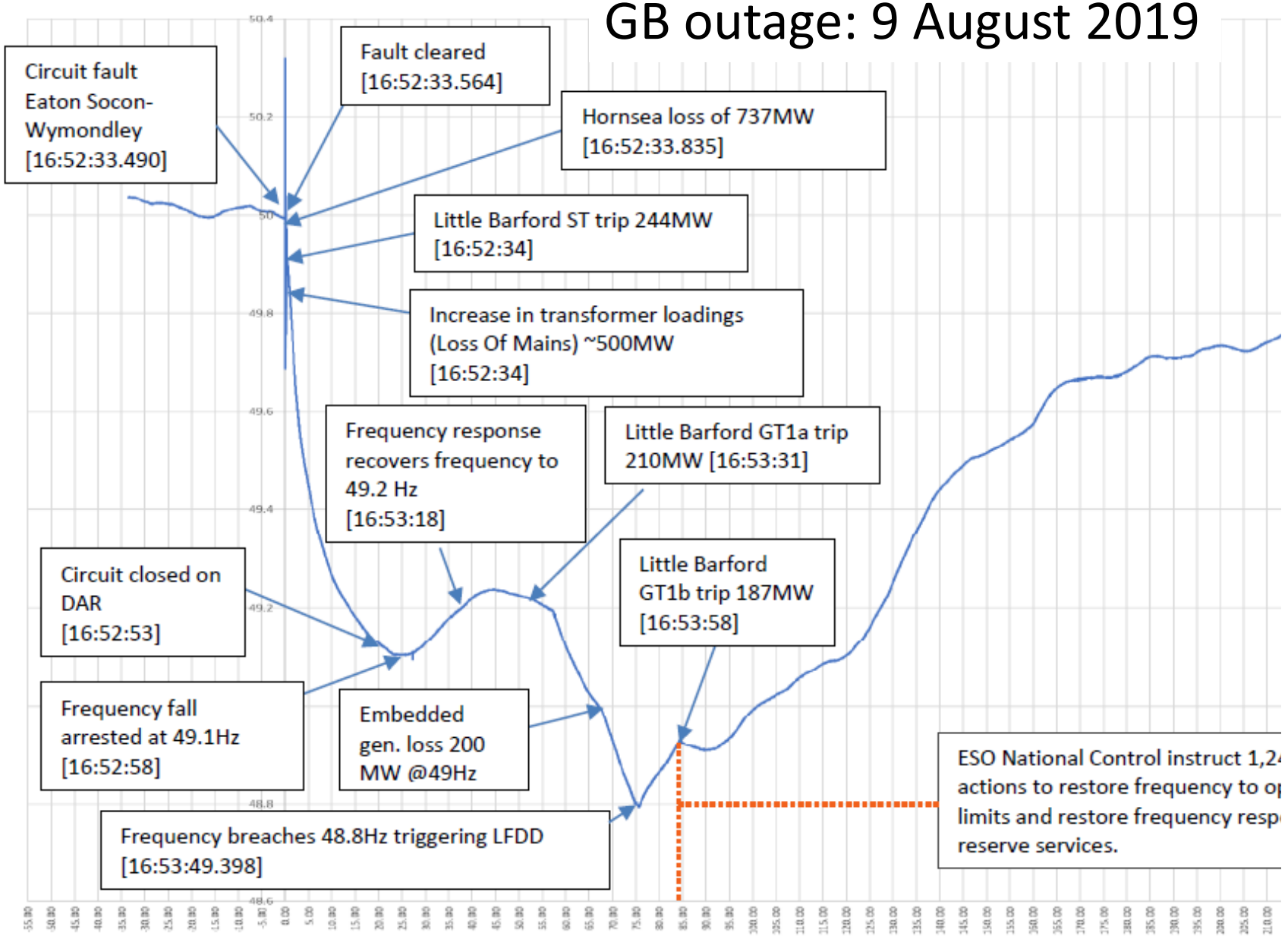
Skolkovo Institute of Science and Technology

Recent outages

- GB: August 2019
- California: August 2020
- Europe: January 2021
- Texas: February 2021

- Is there a common theme?

GB outage: 9 August 2019



- Lightening strike – nothing unusual but two power plants tripped: (N-2) event
- Hornsea offshore wind farm (200 miles away)
  - Commissioned 7 months earlier, fulfilled Grid Compliance only on interim basis
- Little Barford plant - Combined Cycle Gas Turbine (CCGT)
- Additional loss of DG due to fast frequency and voltage changes inadvertently triggering Loss of Mains protection against islanding
- under-frequency load shedding (involuntary) activated when frequency dropped to 48.8 Hz: 1.15M customers, 931 MW

50 Hz restored within 5 mins, full supply restored within 40 mins

Effects on infrastructure: rail

- It was not the outage itself, which lasted only 40 mins, but a rail disruption which caused public anger
- Perfect storm: Friday evening
- Power supply to the tracks was not interrupted but one class of trains failed when frequency fell below 49 Hz
  - They should have operated down to 48.5 Hz
- Knock-on effect – total chaos:
  - Hundreds of trains cancelled
  - Two main London stations closed for several hours

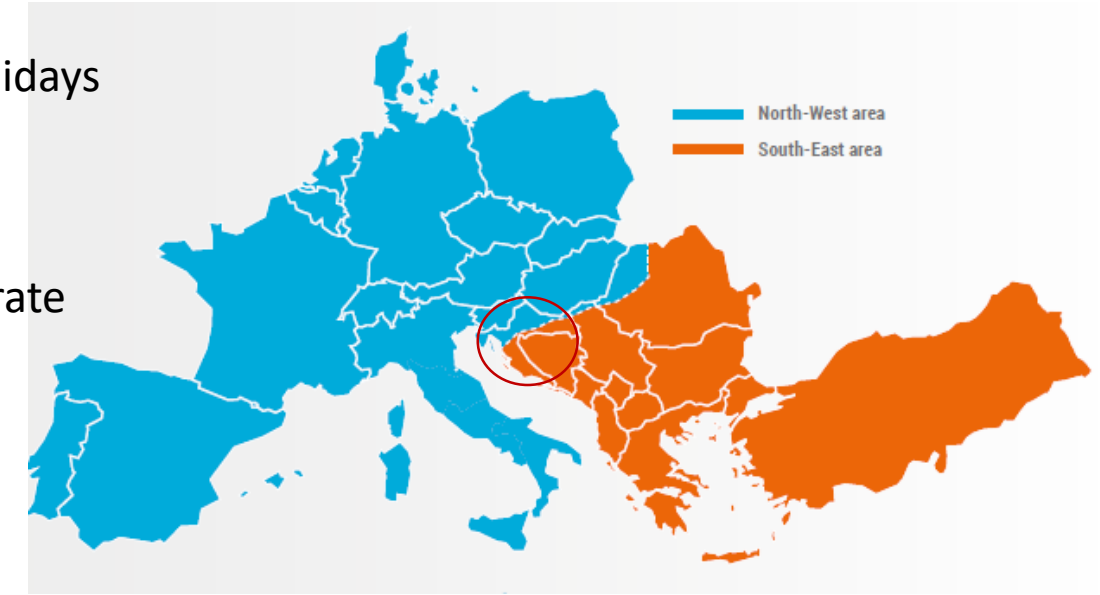
Conclusions for GB outage

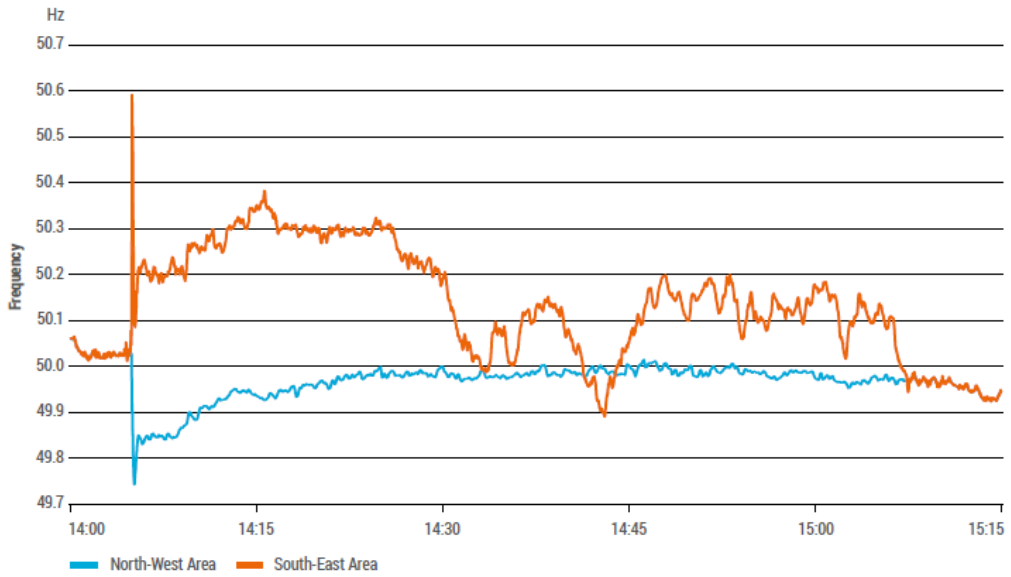
- Power system itself behaved as it was supposed to in response to (N-2) event
- Main recommendations
  - Review security standards
  - Complete Loss of Mains Change (DG) programme
  - Examine interactions with other infrastructures
- Previous GB (N-2) event was in 2008 so maybe one event in a decade is OK?
- Not really – see later

Bialek J. “What does the GB power outage on 9 August 2019 tell us about the current state of decarbonised power systems?” Energy Policy 2020, Vol. 146.

System separation in Europe: 8 January 2021

- Unusual loading situation:
  - low demand in the South due to warm weather and Orthodox holidays
  - higher demand in Central/Western Europe due to cold weather
  - Strong South->North power flows
- A busbar coupler in Croatia trips splitting the substation into two separate units (change of system topology)
  - automatic reconfiguration of neighbouring power flows
  - lines become overloaded
  - a cascade of line trips
  - system separation in 20 seconds
- Frequency falls in North-West due to a power deficit
  - Contracted interruptible loads of about 1.7 GW stabilise frequency
- Main question: it was (N-1) event – so why a cascade?
- Busbar coupler trip was not considered in (N-1) security analysis – it was deemed not dangerous under typical loading conditions





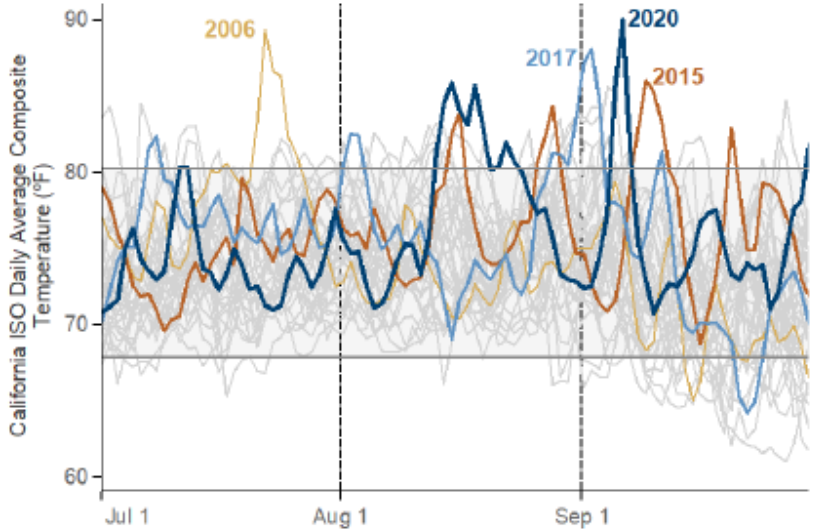
Newcastle University

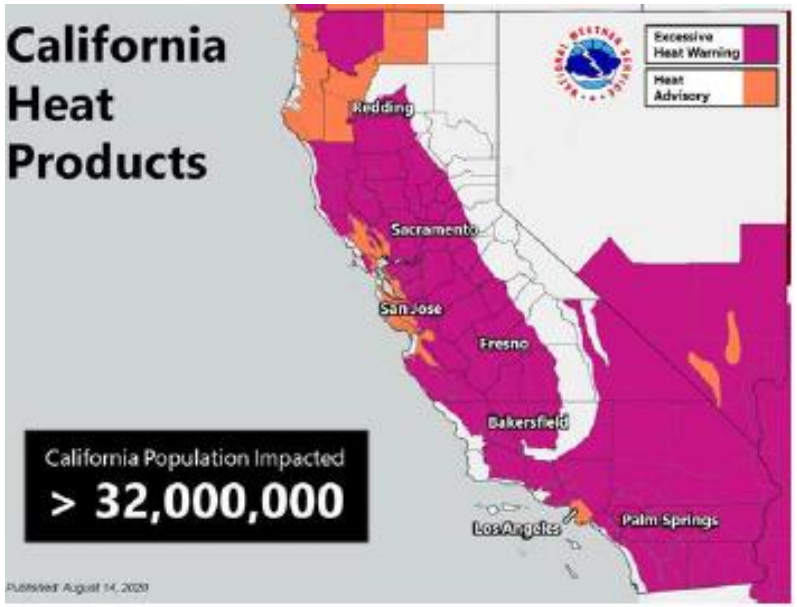
Skolkovo Institute of Science and Technology

California rotating outages August 2020

- “The climate change-induced extreme heat wave result in demand for electricity exceeding existing electricity resource adequacy (RA) and planning targets”
- “resource planning targets have not kept pace to ensure sufficient resources that can be relied upon to meet demand in the early evening hours.”
- “Some practices in the day-ahead energy market exacerbated the supply challenges under highly stressed conditions”

Figure ES.1: July, August, and September Temperatures 1985 - 2020





California ISO: “Root-cause analysis. Mid-August 2020 Extreme Heat Wave” January 13, 2021

Newcastle University

Skoltech
Skolkovo Institute of Science and Technology

What do the GB/Europe/California/Texas blackouts tell us about the current state of decarbonised power systems?

- The direct causes were completely different in each case
- Is there a common theme?
- THE CHANGE

THE CHANGE

- Old world - 20th Century:
  - Controllable synchronous generation, passive demand,
  - SO had detailed models of all the elements: omnipresent and omnipotent god
  - SO had to deal with “known unknowns”
  - Slow changes in technology giving time for getting operational experience
  - The past gave a guide guidance about the future
- The brave new wold (last 10-15 years)
  - Fast changes in technology : wind (offshore!), solar, DG, active demand, batteries, smart grids etc.
  - Little operational experience, rush to commission – see Hornsea
  - “Unknown unknowns”: new controls with unknown interactions and modes of failure (Hornsea)
  - Climate change-induced changes in weather patterns

System Operators

- The old world of omnipresent and omnipotent System Operator is gone
- System Operators were caught off-guard by rapid changes in: technology (GB), flow patterns (Europe), weather (Texas and California)
- Those changes will accelerate due to zero-emission targets (changes in technology and power flow patterns) and climate change-induced changes in weather patterns
- How to counteract
  - Different measures in each case but old security standards should be reviewed
  - Statistical tools could help – but:
    - statistics are based on the past but the future will be different
    - how to account for very rare events (tails in the distribution)?