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

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Recent outages

- Australia 2016
- GB: August 2019
- California: August 2020
- 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
  - Grid Compliance only on interim basis
- Little Barford plant – traditional 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) when frequency dropped to 48.8 Hz: 1.15M customers, 931 MW
  - Full supply restored in 40 mins
  - Power system behaved as it was designed to in response to (N-2) event
  - Everything OK?
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
- Conclusion: need to consider common modes of failure and interconnected infrastructures
California rotating outages August 2020

- Rotating blackouts over a number of days affecting 32M people
- “The climate change-induced extreme heat wave resulted 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.”
  - Duck curve
  - Solar panels provided less power but the demand was still high
- “Some practices in the day-ahead energy market exacerbated the supply challenges under highly stressed conditions”
  - “Any system that can be gamed, will be gamed, and at the worst possible time.” S. D. Freeman, Chair of the California Power Authority, 2001
Texas freeze and blackouts 11-19 February 2021

• Texas is a hot weather state – not prepared for ice storms and long-lasting freeze

• 20 GW peak, 800 GWh load shed – 4.5 million customers, most down for nearly a week; little or no rotation of outages

• widespread hunger, cold, discomfort, life interruption, 50+ deaths, pipe and water system freezes, extensive home and building destruction from frozen water pipes
• 4 min 37 secs away from cascading grid collapse and months until full system restoration
• Would a stronger interconnection have helped?
  • Neighbouring regions experienced similar weather and problems
  • The existing (weak) interconnections were underutilized
• ERCOT has an “energy only” market. Would a capacity market have helped?
  • Yes, but no capacity market could protect against 50% generation loss
• Should the energy market have been suspended?
  • Prices were capped at $9000/MWh
  • Gas prices rose too - interactions between the electricity and gas markets
  • Windfall profits for generators, huge losses for consumers
    • Are the price signals meaningful for such an extreme and rare event?
• Markets blamed for preferring short-term profits over long-term security of supply
  • A similar event Feb 2011, US southwest incl. Texas: 4.4M customers affected but shorter (8h vs 71h) less severe (4 GW vs 20 GW load shed) and not affecting gas supplies
  • 2021 Texas freeze was a more severe “black swan” event
  • No compulsory weatherization, deferred to plant owners
Old world - 20th Century

- Controllable synchronous generation, passive demand
- SO had detailed models of all the system elements (grid, generators, demand): omnipresent and omnipotent god
- Slow changes in technology giving time for getting operational experience
- The past gave a good guidance about the future
- The system was robust:
  - SO knew how to deal with “known unknowns”
  - (N-1) reliability criterion served well
The brave new world (last 10-15 years)

- Fast changes in technology: wind (offshore!), solar, DG, active demand, batteries, smart grids, EVs etc.
- Often little operational experience, rush to commission – see Hornsea
- “Unknown unknowns”: new controls with unknown interactions and modes of failure (Hornsea)
- Common modes affecting interconnected infrastructures (GB, Texas)
- Climate change-induced changes in weather patterns (Australia, California, Texas)
- Past experience does not provide a good guidance any more
- The old world of omnipresent and omnipotent System Operator is gone
- System Operators were caught off-guard by rapid changes in technology (GB) and weather patterns (Australia, Texas and California)
- The system is not resilient: SOs were not able to respond to disruptive events, unknown and common modes failures
- Those changes will accelerate due to:
  - zero-emission targets (changes in technology)
  - climate change-induced changes in weather patterns
What to do?

- Raise the security standard to (N-2) to deal with unknown modes of failure (GB)?
  - Very expensive
  - But security standards should be reviewed (California, GB)
- Design the system to withstand high-impact low-probability (HILP) “black swan” events?
  - uneconomical
- Use more widely statistical tools?
  - Of course, but statistics are based on the past and the future will be different
- What to do?
  - combine robustness with resilience
  - Robustness (20th Century): being not surprised by events (react to known unknowns)
  - Resilience (21st Century): being prepared to be surprised (react to unknown unknowns)
    - Emphasis on restoration
    - Rely more on novel controls rather than costly passive redundancy to maintain security (e.g. (N-1))
    - Microgrids