



Risks to the electricity grid

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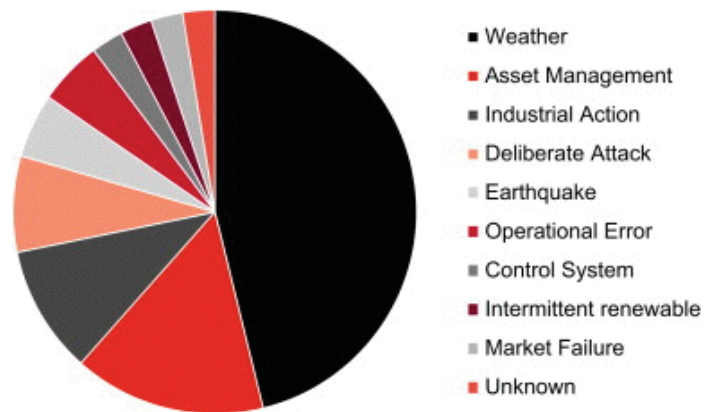
'Sharing Best Practices to Protect Electricity Networks from Natural Disasters'
Vienna, 2.7.2014

Grid trends

- Lots of network integration (e.g. EU grid to Russia, Turkey)
- Trimmed for efficiency, lower transmission capacity margins
- Society is becoming more reliant on electricity for critical services
- Total demand is growing slowly, by ~0.5% per year (Eurostat)
- Distribution grid is becoming 'smart' with bi-directional flows to and from home/cooperative decentralised producers
- Transmission grid will move more electricity further
 - *How much more due to large scale remote renewables?*

Vulnerability to natural hazards

- Most outages are due to storms / weather
 - *How much worse because of climate change?*
- Some due to earthquakes
- Outages may combine hazards with e.g. maintenance and/or management and/or design



Source: EON, via Boston, 2013

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Resilience in electricity networks

Multiple aspects:

- Redundant links
- Isolate outages
- Restore services
- Repair & rebuild infrastructure

Resilience seems to conflict with most of the current grid trends

- How to implement?

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Redundant links

Concept: Multiple ways of getting to each destination

- *How many more separate links would we need? Where?*
- Compare Internet (load-shedding instead of throttling)

Challenges: Governance, huge cost & time

- *Can we meet growing public opposition to new power lines?*
 - Visual disturbance, home values, perceived health risks, ..
 - Weigh several hours of blackout vs. powerline in backyard
- Long process
 - *Can the 6-7 years permit procedures in the EU go faster?*
- First time to build a transmission line is very expensive

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Isolate outages

Concept: sacrifice part to save the whole

- Avoid natural hazards turning into cascade failures
- Decentralised yet integrated grid

- Add manual/automatically triggered cutoff 'borders', or
- desynchronise and add back-to-back connections w/ breaker

Challenge: Complexity, cost

- Less 'network mass' to absorb demand shifts
- *Who pays for complex and expensive interconnects?*
- *How many new transmission lines would we need?*

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Restore services

Concept: Get electricity flowing again as soon as possible

- Duration matters: 15 second is a glitch, 15 minutes is usually fine, 15 hours is bad, 15 days can be lethal
- Impact depends on place, season and service
- Civil protection become involved between >15 minutes
- Major operation for outages >15 hours

Challenges: Logistics, funding

- *How to have sufficient equipment (generators, ...) available?*
- *How to move equipment to where it is needed quickly?*
 - Sparsely populated areas have lower priority in response

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Repair & rebuild infrastructure

Concept: Get electricity flowing again as soon as possible

- Duration matters: 15 second is a glitch, 15 minutes is usually fine, 15 hours is bad, 15 days can be lethal
- Impact depends on place, season and service
- TSOs/DSOs reroute power and/or rebuild network
- Duration and priorities determine civil protection mission

Challenges: Equipment, funding

- *How to have sufficient equipment (cranes, hardware) ready?*
- Large transformers are rare or unique, leads to long delays
 - *If we standardise parts, how to avoid 'monoculture' risks?*

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Grid inertia

Temporal disconnect

- Natural hazards are snapshot events, happen in hours
- Building resilience is a long process, requires many years

Physically adapting the grid takes a long time

- ENTSO-E makes 10-year plans
 - *Lots of consultations, do they include the right institutions?*
- Building infrastructure takes 5-20 years
 - *Lots of stakeholders, are they engaged usefully?*
- Changing attitudes and priorities can take forever

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Thank you for listening

Comments?

Discussion?

Questions?

Further reading

- Boston, 2013
<http://dx.doi.org/10.1016/j.enpol.2012.02.004>
- Hines, Balasubramaniam & Sanchez, 2009
<http://dx.doi.org/10.1109/MPOT.2009.933498>
- Johansson, Johansson & Johansson, 2007
<http://inderscience.metapress.com/content/BU8JBMGBHYE8J3DM>
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<http://dx.doi.org/10.1016/j.enpol.2009.11.047>
- Ward, 2013
<http://dx.doi.org/10.1007/s10584-013-0916-z>