Impact of uncertainties on strengthening power system resilience to extreme weather: where, when, how

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Introduction

- Actions needed for climate change adaptation in power systems
- Climate change adaptation in power systems can be achieved with improvements in resilience to extreme weather events
- Uncertainties in power systems and extreme weather events bring uncertainties to power system resilience enhancements

Overview of uncertainties

Where?

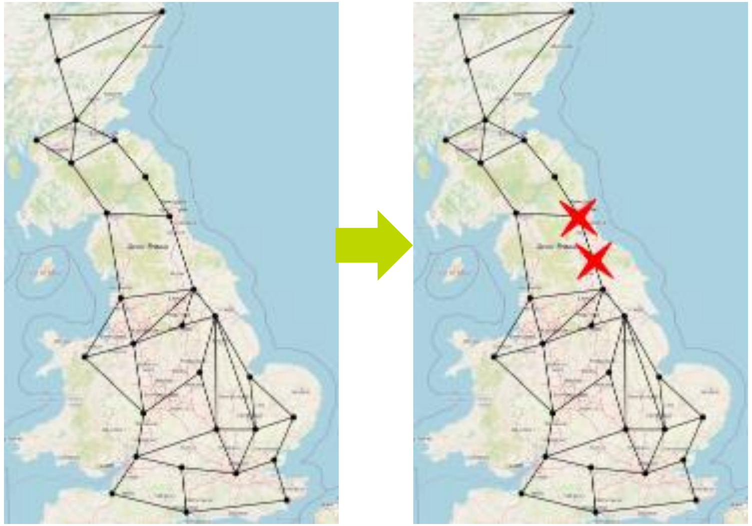
- Affected locations
- Out-of-service power system components
- Cascading effects

When?

- Occurrence time
- Time to prepare

How?

- Alternatives to improve resilience



- Disabled line or substation?
- In 1 h or 1 day?
- Underground line or reconfiguration?

Overview of uncertainties

- Dealing with uncertainties
  - Stochastic optimization
    - Monte Carlo simulations
    - Chance constraints
  - Deterministic optimization
    - Worst-case scenario
    - A range of representative scenarios

Application examples

- Description
  - 29-bus GB transmission system
    - ➢ 29 buses: aggregated generation and transmission loads
    - ➢ 99 lines: 49 double circuits, 1 single circuit
  - Operation in a stormy day
    - ➢ weather data (forecasts) define affected locations
    - ➢ power outages: (coincident) line tripping triggered by permanent fault
    - ➢ out-of-service lines affect the system's ability to supply loads
    - ➢ preventive generation dispatch to minimize lost loads
    - ➢ 24 h time horizon with reliable weather forecasts 6 h ahead
  - Objective: minimize energy not supplied subject to power flow constraints

Application examples

- Optimization problem

$$\min_{t} \sum_{k \in K} \sum_{i \in I} D_{t,k,i} - d_{t,k,i}$$

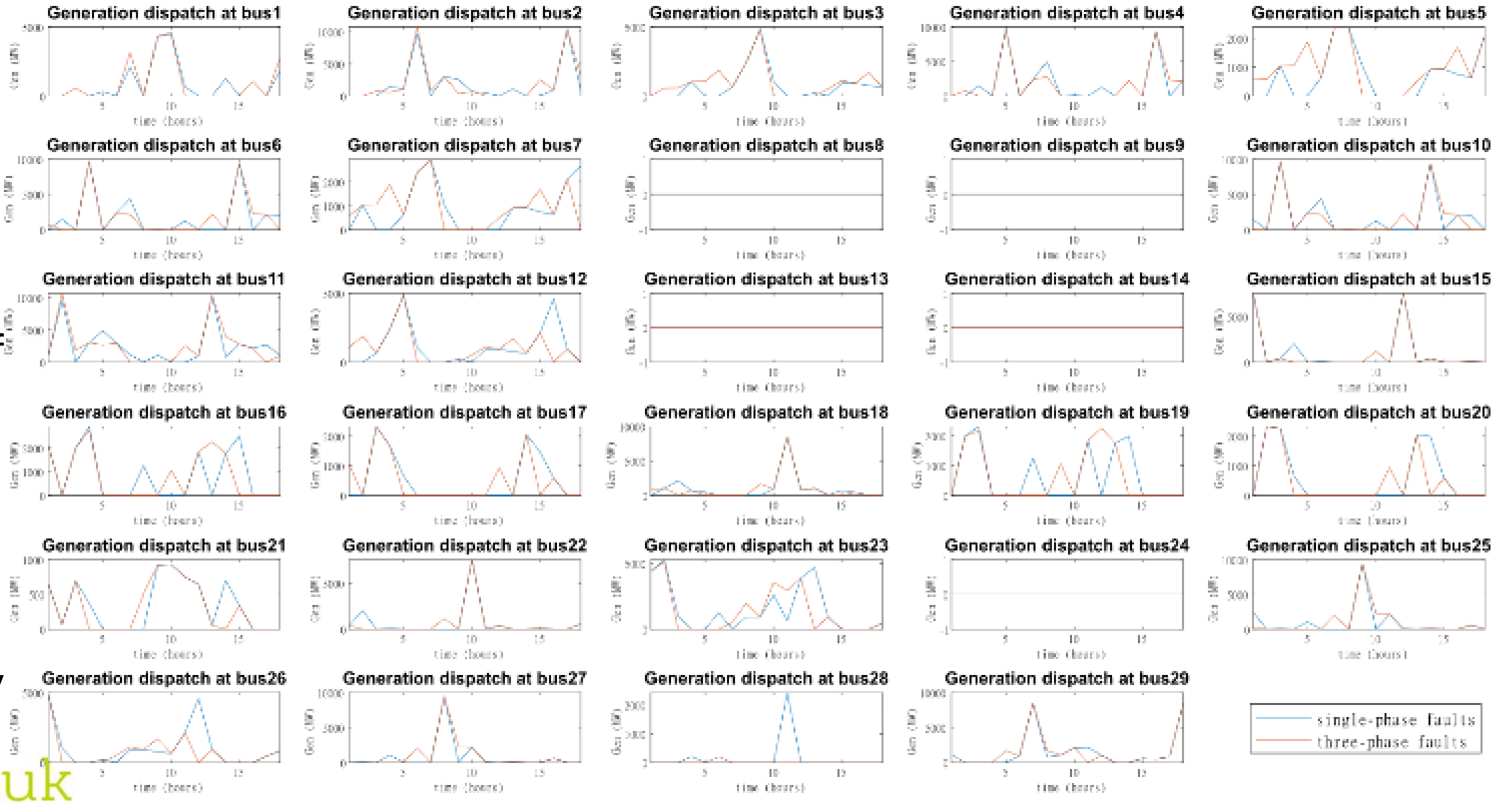
- Subject to

$$0 \leq d_{t,k,i} \leq D_{t,k,i}$$
$$0 \leq g_{t,k,i} \leq G_{t,k,i}$$
$$f_{t,k,l} \leq M\left(1 - A_{t,k,l}\right) + B_{t,k,l}\left(\theta_{t,k,OR(l)} - \theta_{t,k,DE(l)}\right)$$
$$f_{t,k,l} + M\left(1 - A_{t,k,l}\right) \geq B_{t,k,l}\left(\theta_{t,k,OR(l)} - \theta_{t,k,DE(l)}\right)$$
$$\sum_{l \in L | OR(l) = i} f_{t,k,OR(l)} - \sum_{l \in L | DE(l) = i} f_{t,k,DE(l)} = g_{t,k,i} - d_{t,k,i}$$

- Case studies
  - Impact of extreme weather is worse than expected: disabling of all phases instead of a single-phase
  - Extreme weather hits the grid before or after forecast time: effect on power outages
  - Random number added to load demand: maximum variation of ±10%

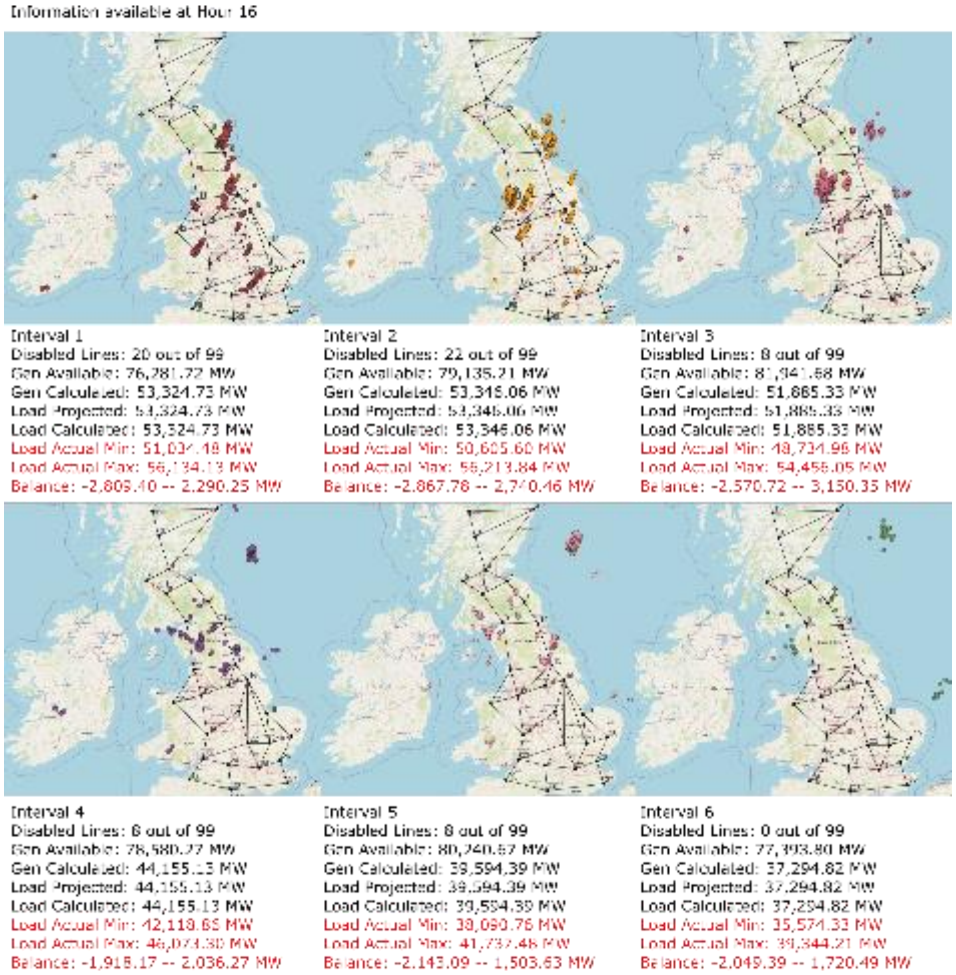
Results

- Impact of extreme weather is worse than expected: disabling of all phases instead of a single-phase
- Generation dispatch by bus



Results

- Extreme weather hits the grid before or after forecast time
  - Changes in out-of-service lines
- Random number added to load demand: ±10%
  - Changes in total load demand and power imbalance



Discussion

- Enhancements in power system resilience to extreme weather are affected by uncertainties
- The selection and implementation of preventive measures for power system resilience enhancements to extreme weather depend on
  – operating conditions of the grid
  – severe weather conditions
  – accurate information
  – constraints
- Power system resilience enhancements are limited if prepare for one scenario and it does not occur

Conclusions

- Uncertainties in power system operation and severe weather conditions make an influence on the selection of resilience enhancement measures in different ways
- Deterministic impact assessment of extreme weather events on the grid over a range of scenarios
- Optimization problem aimed at minimizing the energy not supplied defines appropriate resilience enhancement strategies
- Power system resilience enhancements are limited if prepare for one scenario and it does not occur

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Thanks for your attention.

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