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Security Analysis of the Operations of Interdependent Electric and Gas Networks

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Introduction

- **Gas and electrical infrastructures** are strongly **interdependent**
- These **interdependencies** are meant to **strengthen** in future scenarios with **large renewable share**
- The **aim** of this work is **to assess the ability** of the electrical and gas infrastructures **to withstand and absorb** the effects of **contingencies** through the adaptation and the restoration of their **coupled operations**

Method

- The **electrical network** is represented by a **steady-state DC power flow model** that can detect line failures and **cascading failures** events
- The **gas infrastructure** is modelled through **a transient one-dimensional flow** representation, that solves **mass conservation** (1) and **momentum** (2) equations, and accounts for the operations of **compressors**, **pressure regulators** and **storages**

$$\frac{\partial M}{\partial x} + S\frac{\partial \rho}{\partial t} = 0 \quad (1)$$

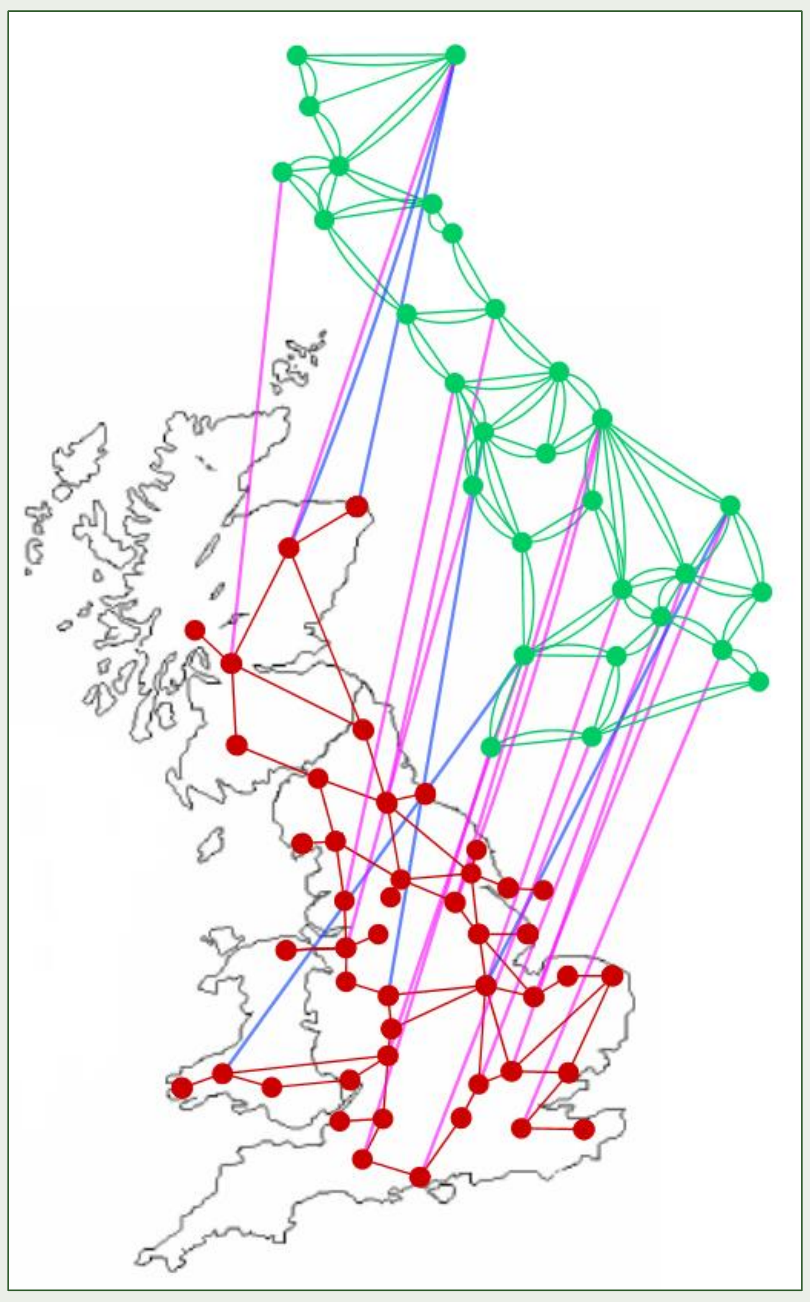
$$\frac{\partial \rho}{\partial x} + \frac{\lambda|\omega|}{2DS{\omega^2}_{sd}} M + \rho\left(g\frac{\Delta h}{L{\omega^2}_{sd}} + (1+b^*\rho)\frac{\Delta\theta}{\theta L}\right) + \frac{1}{S{\omega^2}_{sd}}\frac{\partial M}{\partial t} = 0 \quad (2)$$

- The **coupling** is achieved via gas-fired power plants (**GFPP**) and **electricity-driven compressors.** GFPP power and gas off-takes are related by (3):

$$GFPP_{Pw} = M_{off-take} * HHV * \eta \quad (3)$$

- **Corrective actions** and safety strategies of transmission system operators **to ensure safe operations** of the infrastructure elements, i.e. **pressure** and **power flow limitations**, are modelled in terms of **generation redispatch**, gas and electrical **curtailments** and **gas storage activation**

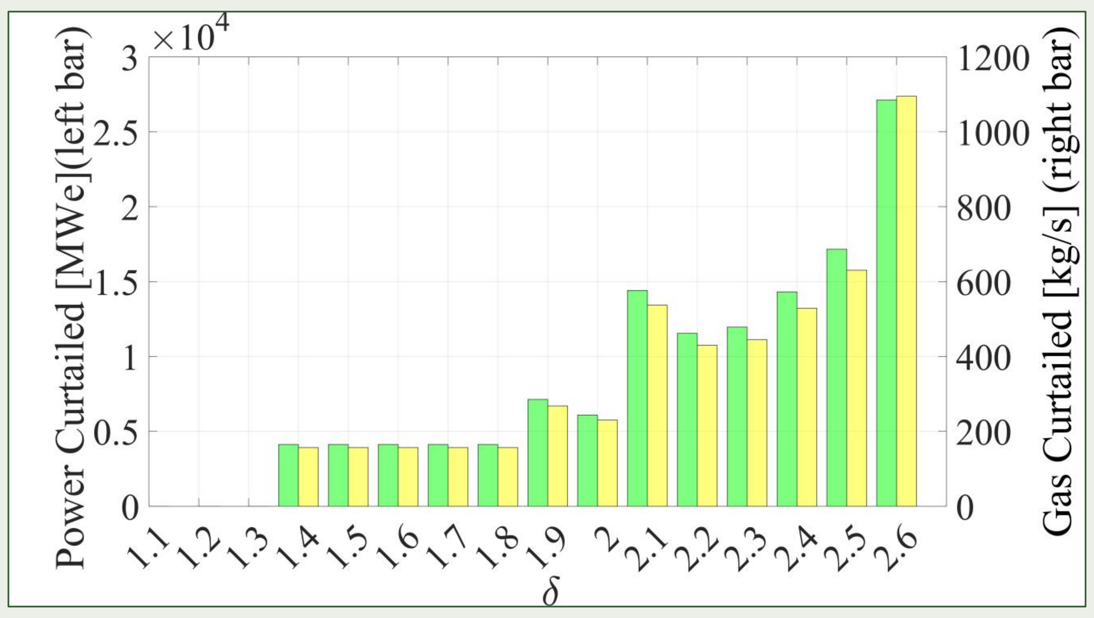
Case Study



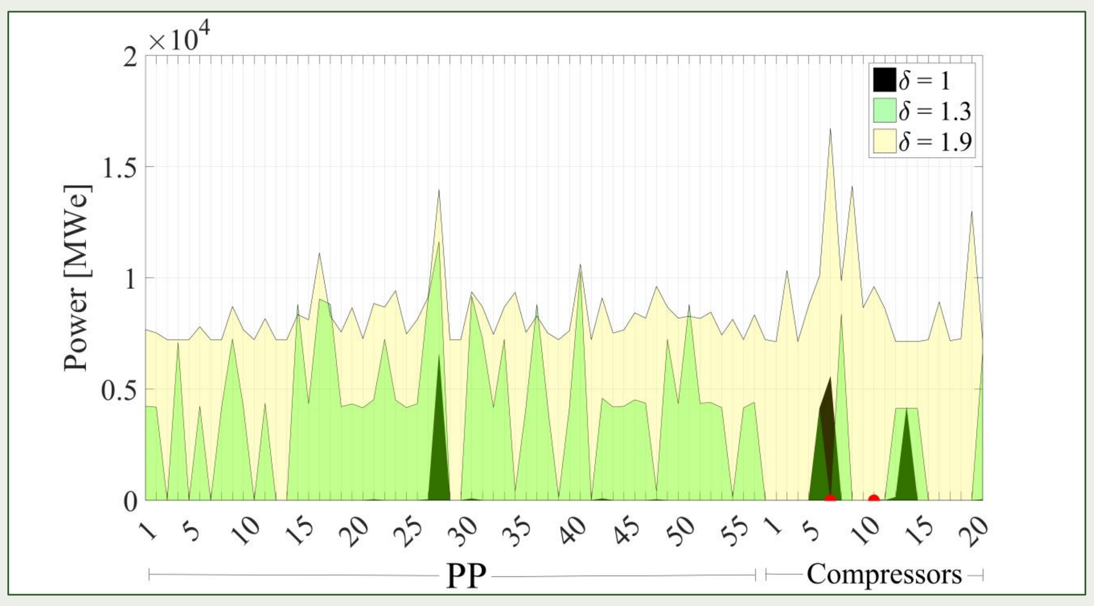
- 99 electric lines
- 27 electric busses
- 78 gas nodes
- 89 gas pipelines
- 21 compressor stations (5 electricity-driven)
- 9 wind farms
- 57 generators (GFPP, nuclear, coal, hydro)

- Total non-electric gas demand: 268 *mcm/day*
- Maximum electric demand: 52.7 *GW*

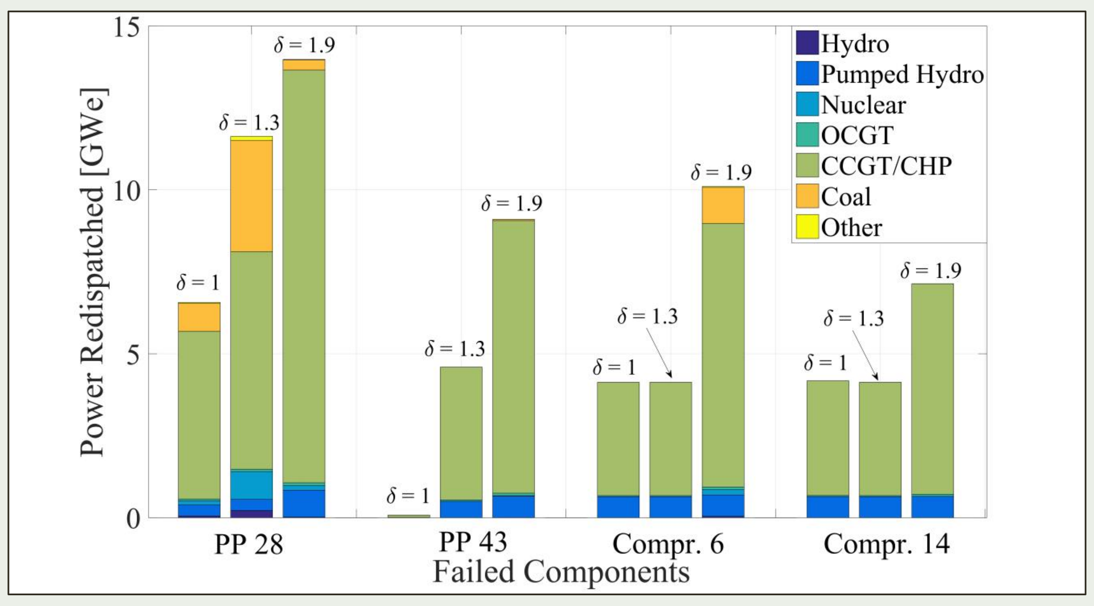
Results



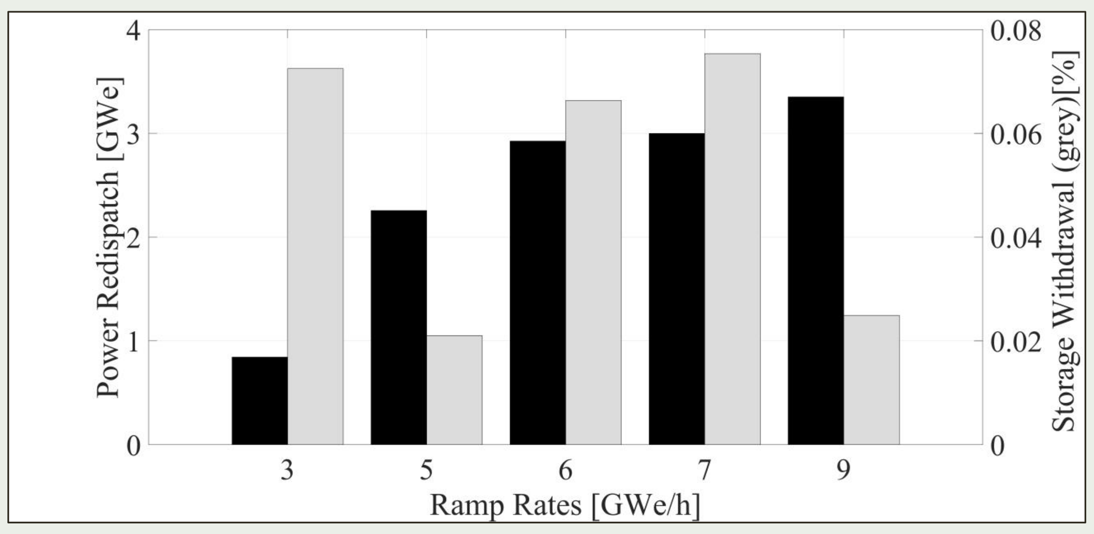
The **interdependent** electric and gas **systems** can **sustain** an **increase** in **gas demand** equal to **30 %**, δ = 1.3, of the base scenario (268 *mcm/day*), without endangering normal operations



The **redispatched power**, induced by the failure of one component, **increases with** the level of gas demand (**δ**)



GFPP and **pumped hydro** are requested for **compensating** the **loss** of a **component**, due to their large ramp rates. **Coal units** are requested when **pressure violations** temporary **limit GFPP** capacity



Sudden **RES ramp-down events** require balancing by conventional generators and **cause gas-constraint violations**. To comply with gas safety margins, **10-20%** of the **power increase needs** further **redispatching**. **Storage withdrawals** are affected by **gas curtailments** and by the **ramp-down magnitude**

Conclusion

- Results show **criticalities** in the GB gas network infrastructure
- **No cascading failures** occur across networks
- A condition of **30% increase** of the **peak gas demand** is a **limit for safe operations**