RWTH AACHEN UNIVERSITY

E.ON Energy Research Center
ACS | Institute for Automation of Complex Power Systems

Master-Thesis:

Interdependency and Uncertainty in a Graph-Based Approach to Complex Power System Modelling and Analysis

Context:
In times of climate crisis and increasing global tensions, a fundamental transformation of energy supply systems is necessary to ensure the security, environmental compatibility and independence of energy supply. The power grid plays a key role in this transformation by replacing fossil power plants and integrating additional consumers, from industrial processes to heat pumps and electromobility. Consequences of this ongoing transition include stronger sector coupling (Power-to-X) and integration of modern ICT into the automation infrastructure in order to coordinate millions of decentralized generation plants and consumers safely and reliably. The interdependencies of systems in different domains and their aspects have been described in [1] on a high level.

As both ICT and electrical systems are network infrastructures, they have been modelled as graphs, usually with vertices representing nodes in the ICT or electrical grids and edges representing communication links or power lines. Graphs have also been used to model interdependencies between these two domains and to analyze failure cascades in to global interdependent network (caused by mutual dependencies between electrical and ICT components). However, these approaches are usually limited to two different domains, while real systems can be more complex and consist of more domains. An approach to extend the graph representation to systems with more than two domains is shown in [2]. Also, the simulation of cascading failures is usually based on the assumption, that each component only has two states (operation and failed) and dependencies lead to a certain failure of the depending component if the supporting component fails. In real systems, this might not be the case – instead of failing instantly, depending components could be operational, but with a higher probability to fail in a certain time frame, or the service they provide could degrade. Finally, graph representations are often limited to the topology of the modelled network, disregarding domain-specific characteristics. This is addressed in some approaches for single-domain systems, but not for interdependent multi-domain systems.

Starting from the identification of current graph-based approaches to model interdependent multi-domain systems to analyze cascading failures and identify critical components; and the identification of their current shortcomings, the scope of this thesis is to propose an improved approach for modelling these systems, addressing identified shortcomings, based on a relevant example case. Following the proposed approach, the system defined in the example case is to be modelled and used to simulate cascading failures and identify critical components.

Your tasks:

- Critical literature review on what is the state-of-the-art for modelling of interdependent systems, with a focus on power systems
- Investigation of existing approaches and their shortcomings and gaps to include
  - Partial failure and degradation of service quality
  - Uncertainty of failures
  - More than two interconnected domains
  - Domain-specific characteristics (e.g., power flows, latency and throughput)
- Development of a modelling approach to overcome these shortcomings
- Definition of a relevant example case
- Modelling and analysis of the example system, including simulation of cascading failures and identification of critical components

Your profile:

- Student of Electrical Engineering or similar
- Knowledge of non-electric energy systems and/or ICT and automation systems is a plus

Notes:

The supervision can be in German or in English

References:

[1] S. M. Rinaldi, J. P. Peerenboom, and T. K. Kelly, ‘Identifying, understanding, and analyzing critical infrastructure interdependencies’, IEEE Control Systems Magazine, vol. 21, no. 6, pp. 11–25, Dec. 2001, doi: 10.1109/37.969131.

[2] N. Wirtz and A. Monti, ‘A Flexible Framework to Investigate Cascading in Interdependent Networks of Power Systems’, in 2020 6th IEEE International Energy Conference (ENERGYCon), Sep. 2020, pp. 38–41. doi: 10.1109/ENERGYCon48941.2020.9236542.

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