An Approach for Analyzing the Impacts of Smart Grid Topologies on Critical Infrastructure Resilience

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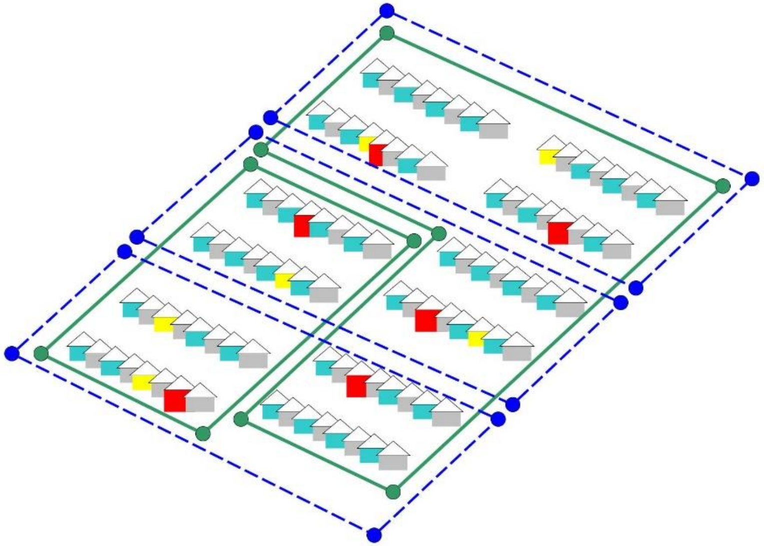
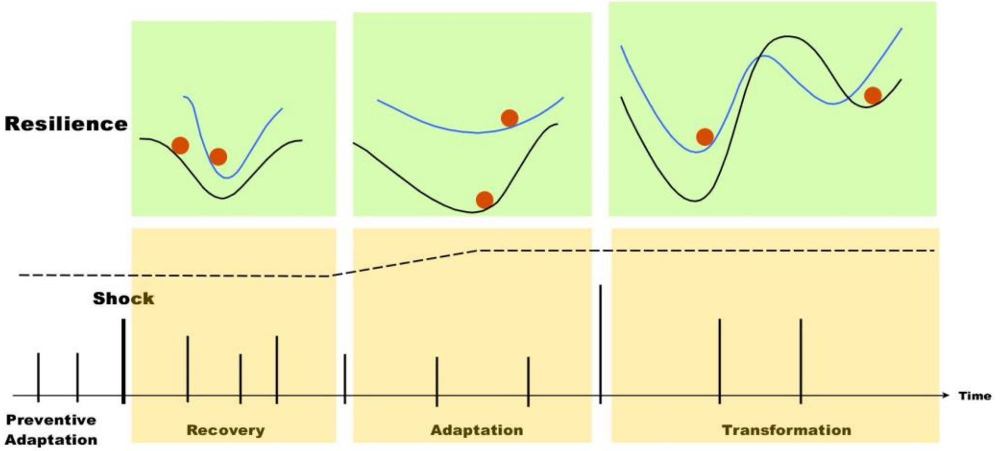


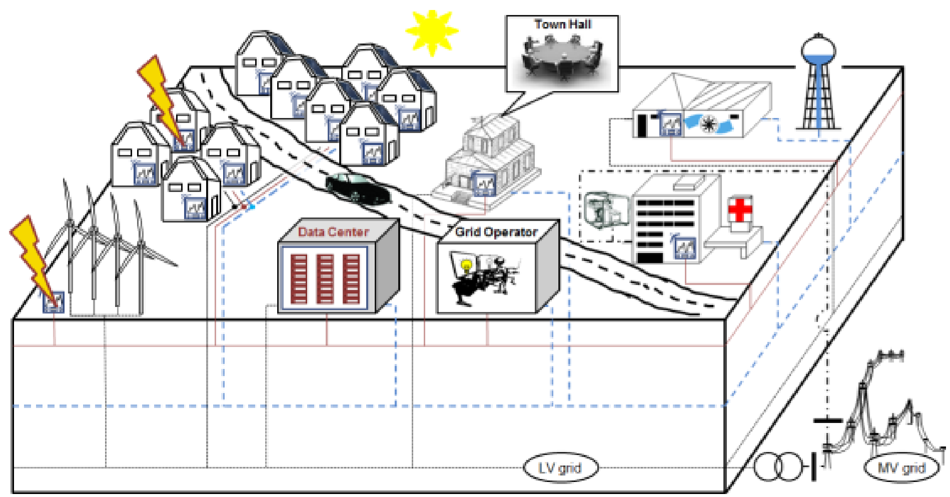


Urban Resilience and Critical Infrastructures

We regard the urban resilience aspect that considers the degree of continuous supply of urban critical infrastructure (CI) services during crisis situations.

Most of the CIs e.g.

- hospitals,
- pharmacies,
- traffic and transport systems



rely on electricity.

Hence the electricity grid may be regarded as a *1st order* CI.

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Transformation Processes & Power Grids

The generation and supply of electricity is currently about to undergo a fundamental transition!

The classical power distribution grids are transformed into **smart grids**, enabling power consumers to produce and distribute electricity.

In the context of cities smart grids may be conceived as a

- huge and complex power and ICT network,
- structured in different ICT network layers and
- equipped with a data and energy management system on top.

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Smart Grid Vulnerability & Urban Resilience

Smart Grid Vulnerability:

The proper functioning of a smart grid highly depends on the proper functioning of a huge amount of technical devices e.g. **smart meters** forming network nodes.

- ➢ Cyber attacks like denial-of-service attacks may lead to power outages.

New dependencies:

The degree of **ICT penetration**, **interconnectedness** and automation increases more and more and urban systems are transformed into **smart cities**.

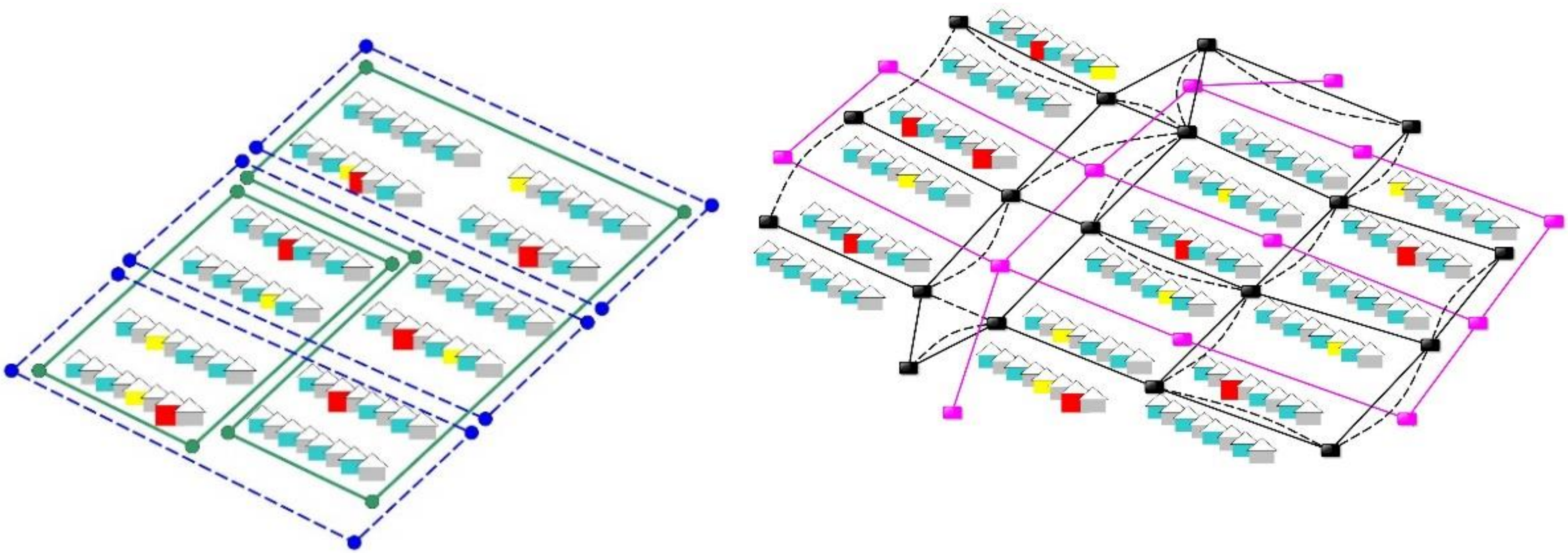
Consequence:

The severity of the impact of electricity outages on an urban system increases.

Smart Grid Topologies & Urban Resilience

Topological degrees of freedom:

- Decomposition of smart grids into micro grids.
- Configurations of components.



How do these degrees of freedom influence urban resilience?

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Topological Degrees of Freedom & CI Relevancy

Considering the welfare of an urban population the **significance** or **relevancy** of a CI may be different compared to another CI.

- During a crisis the relevancy of a CI may vary.

I. Smart grids decomposed into micro grids:

- CIs of high *initial* relevancy shouldn't be accommodated in one micro grid.
- Not *too* many CI entities of one type should be located in a small number of micro grids.
- ➢ A micro grid suffering from cyber attacks can be switched into island mode i.e. disconnected from the smart grid – but services of *many* relevant CIs of different types are still running.

II. Configurations of components:

- Redundancies: CIs of high *initial* relevancy could be virtually located in more than one micro grid e.g. by applying more than one smart meter.
- ➢ If a smart meter shouldn't work due to a denial-of-service attack another still working smart meter can ensure a continuous supply of power.

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Agent Based Modelling – Model Parameters

- CIs and their components are modelled as agents which interact with each other and their environment.
  - In case of a disruption, agents start negotiations and trigger counter-measures.
- Future- and disruption scenarios are flexibly parametrizable and specifiable resp.
  - Most promising future trends e.g. smart grids are modelled.
  - Disruption is defined as a temporarily outage of service provisioning.
- Vulnerability- or resilience analysis.
  - Depending on chosen weights or protection targets the provision of CI services can be evaluated.

Smart Grid Topology & *Model Parameters*

Coupling CI-, ICT- and Power simulation modules:

- At KIT we established a cooperation between power grid and ICT experts who themselves established their own simulation software:
  - I.e. our CI simulation tool and the ICT- and power simulation modules are going to be coupled soon.

Modelling different smart grid topologies:

- According to the smart meter existence information and further *topological constraints,* which the CI simulation module transfers to the ICT simulation module, different *reasonable* smart grid topologies can be instantiated.

Urban Resilience Analysis & Decision Support

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Simulations testing different topologies:

- Fixing a smart grid topology *plausible* disruptions stemming from a *category of plausible disruption scenarios* are simulated.
- The same is done with other smart grid topologies taking *equivalent* disruptions from the same category of plausible disruption scenarios.
- Finally, an *analysis* identifies those smart grid topologies that are more **robust** than others.

Decision support in the design phase:

- Simulation studies can be applied to support city planners enrolling smart grids in an *urban resilient way*.

Thank you for your attention

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