POWER GRID PLANNING AND OPERATION WITH GROWING SHARES OF WIND AND SOLAR ELECTRICITY: CHALLENGES AND SOLUTIONS FOR POLICY MAKERS – BERLIN, APRIL 11, 2019

Novel ways of increasing the utilization of existing infrastructure

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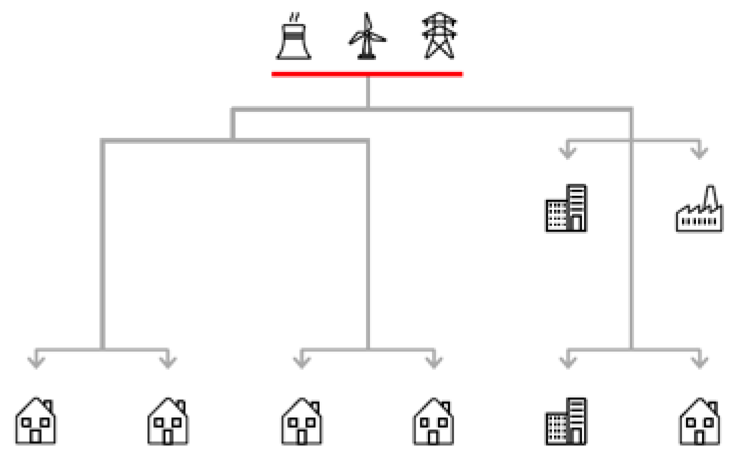
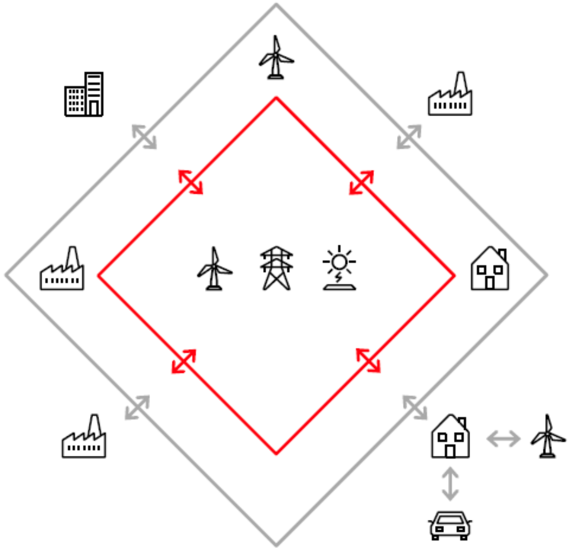
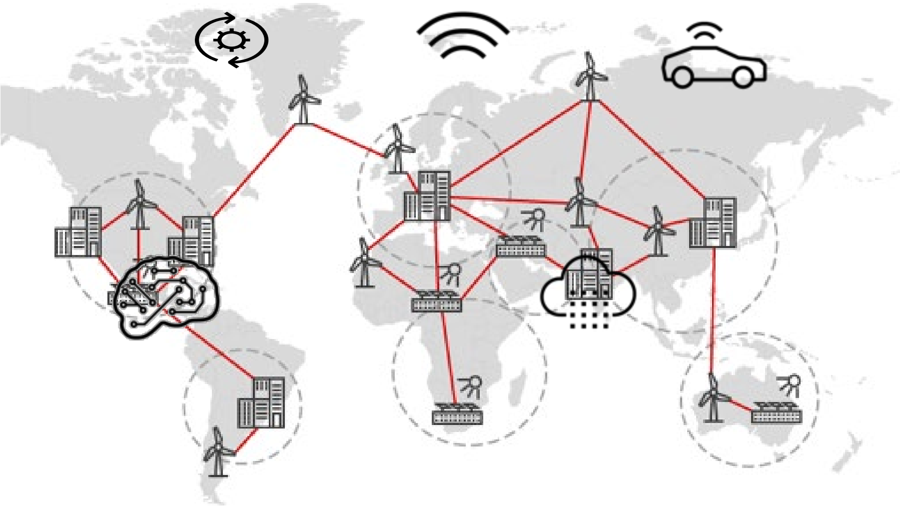
Power systems of the future

From a few well controlled generating units to a myriad of distributed, autonomous generators and loads

Yesterday	Today	Tomorrow
		
– Humans fully in charge – Well established principles and processes	– No full control over generation, neither load – Emergence of (some) autonomous systems	– More functionality given to “machines” – Emergence of AI and its influence in processing data

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Why talking about novel ways to operate networks?

Where do we come from and where are we heading to?

The past: clearly structured, prevention was key

Balancing of load and generation based on a relatively small number of fully controllable power stations

Regional balance of load and generation was the rule,
long-distance transmission the exception

If there was bulk long-distance transmission, it was usually realized by dedicated, controllable HVDC[1] lines (point-to-point)

Only two, stochastic processes: load and failure of components

System operation was based on thorough preparation and sufficient reserves (over-capacity) to deal with any unexpected situations (static (n-1) criterion)

Networks could only respond slowly to new situations

[1] HVDC: high-voltage direct current

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The future: much more diverse, responsiveness is key

Balancing to be realized by using millions of distributed resources

Significant regional imbalances, varying over time

Long-distance transmission becomes the rule rather than the exception

Transmission patterns will vary
⇒ dedicated, controllable lines will not solve this problem, instead the transmission grid as a whole needs to deal with it

Responding to unexpected situations will become more important, thorough preparation is not sufficient any more

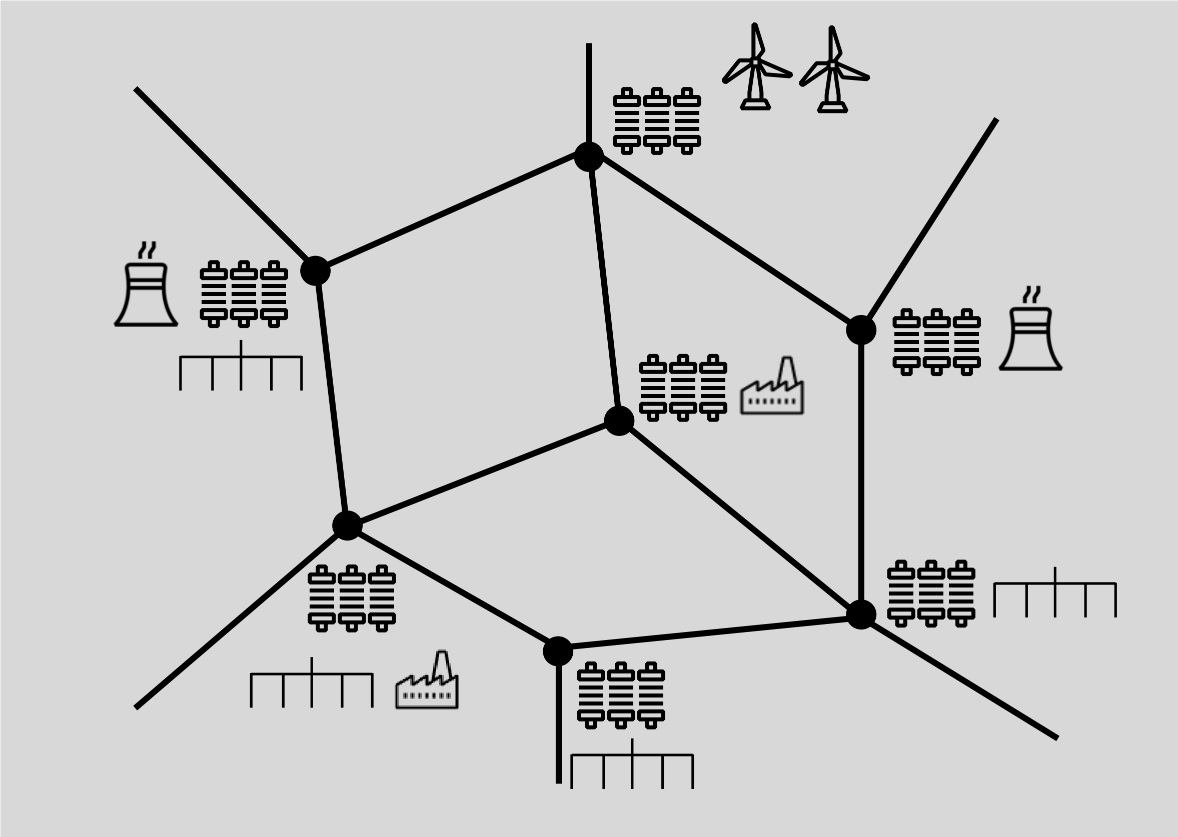
More flexibility and faster responses within the networks required

New requirements will have to be translated into new solutions and new operating principles.

[1] HVDC: high-voltage direct current

Where do we come from?

Meshed AC[1] networks without any active elements



Normal operation

Load-flow control by transformer settings and reactive power, primarily from generators

Limited degree of freedom to influence load-flow – networks needed to fit to their tasks

Lines may be under utilized in case of mismatch between network topology and distribution of load and generation

In case of emergency

Adapting network settings is a slow process

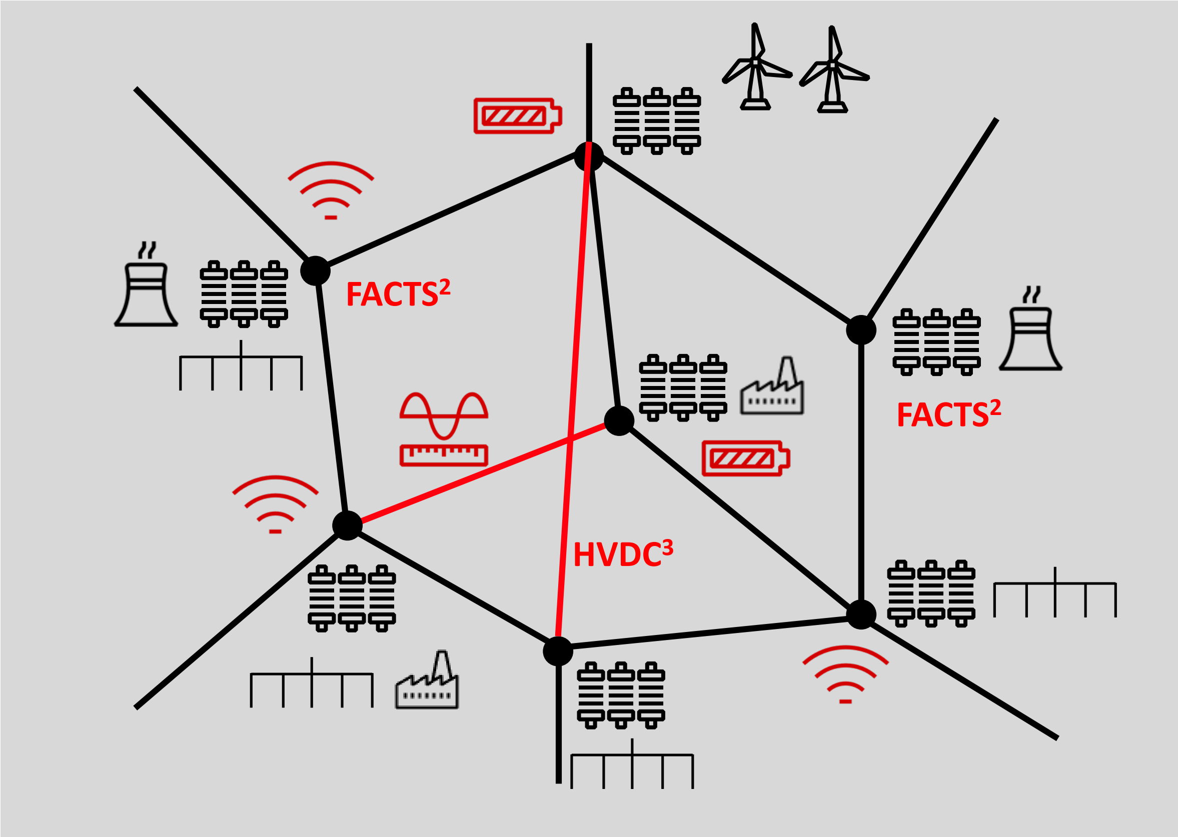
This means that in case of **any** component failure the network requires sufficient reserve capacity to accommodate the new load-flow situation without any adjustments

This results in significant over-capacity in the network

[1] AC: alternating current

Step 1: Increasing operational degree of freedom with new components

Meshed AC[1] networks with active components and increased transparency



Normal operation

Load-flow control in addition by FACTS and HVDC links

Increased degree of freedom to influence load-flow – networks can better be adapted to varying tasks ⇒ increased utilization

Batteries may break peaks

Better information (e.g. line monitoring, PMUs[4]) allows operation closer to the limits

In case of emergency

Additional degree of freedom

Faster components

However, without suitable software on system level and system-wide coordination, no fundamental changes
⇒ still significant reserves because pf preventive approach

1 AC: alternating current
3 HVDC: high-voltage direct current
2 FACTS: flexible AC transmission systems
4 PMU: phasor measurement unit

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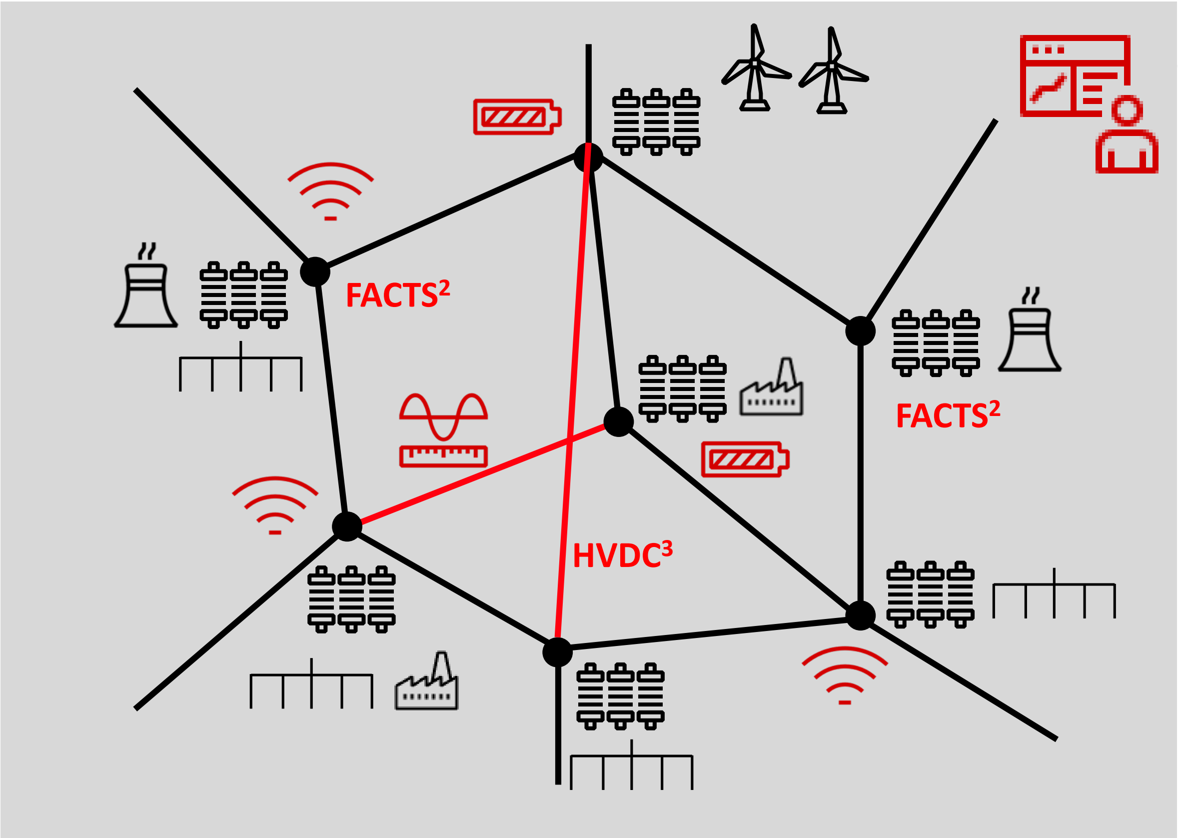
Step 2: From preventive to curative operation

Meshed AC[1] networks with active components, increased transparency and advanced control systems



Normal operation

No additional, new components

However, as there is less need for capacity reservation for emergency situations, grid utilization can be further increased

In case of emergency

Dynamic online security assessment

Curative measures benefitting from fast, power electronic based actors (HVDC[3], FACTS[2]) and precise information (e.g. PMU[4], line monitoring)

Controlled overloading of components

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How get most out of the electricity infrastructure?

Summary

Future electricity networks are facing different challenges than in the past
- More long-distance transmission
- Strongly varying load-flow patterns
- Much higher dynamics

A toolbox for increasing operational flexibility is available
- Non-conventional, but proven solutions: FACTS[2], line monitoring, high temperature conductors, HVDC[3]
- Innovative solutions: e.g. batteries for peak shaving of transmission lines
- Sensors allow operating assets closer to their limits or even (temporarily) beyond

New operating principles may unleash further capacity
- Changing from preventive to curative operation
- Requires coordination of all system participants

Available solutions allow a step-wise transformation of existing networks.

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