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Influence of offshore wind farms on the European electricity market and transmission system

Christian Rathke, RAVE 2012, Bremerhaven, 09.05.2012

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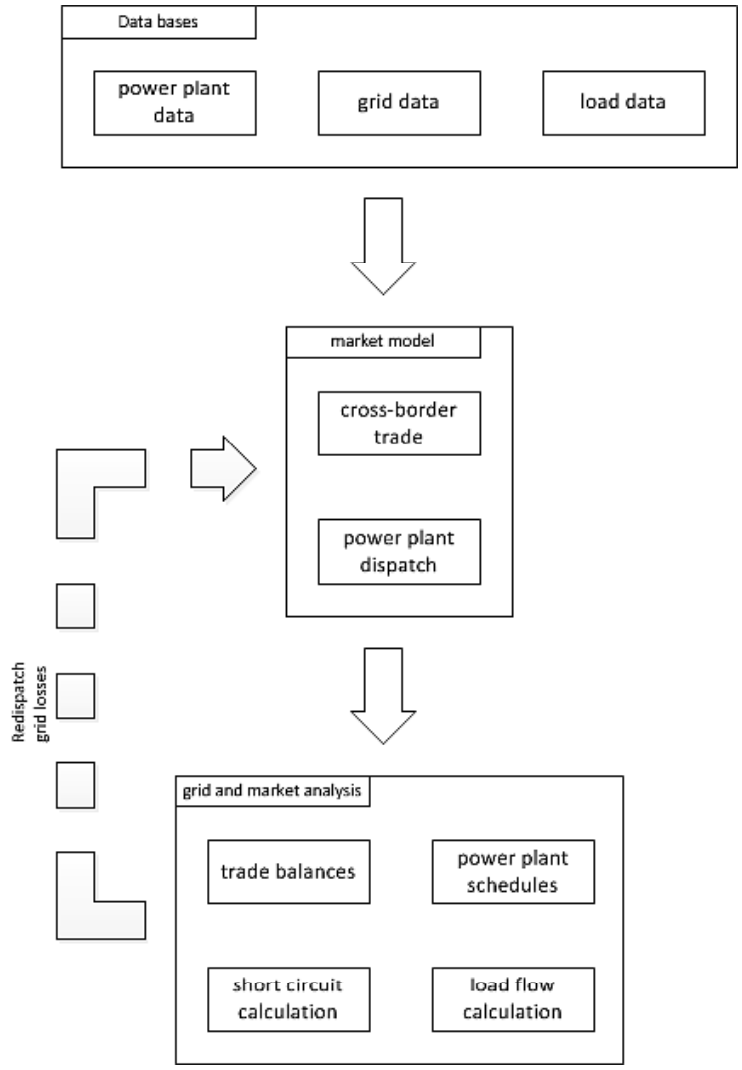
Introduction

- Expansion of renewable energy sources
- Increase of the international electricity exchange
- Future changes in electricity production and consumption
  - Abandoning of nuclear power plants in Germany
  - Erection of new storage power plants
  - Electric mobility
- Extension of European electricity grids is necessary

→ Demand of a software which combines electricity market simulation and grid calculation to describe the physical impact of renewables on the transmission grids

→ Data should be publicly available to allow a reproducable and independent scientific analysis

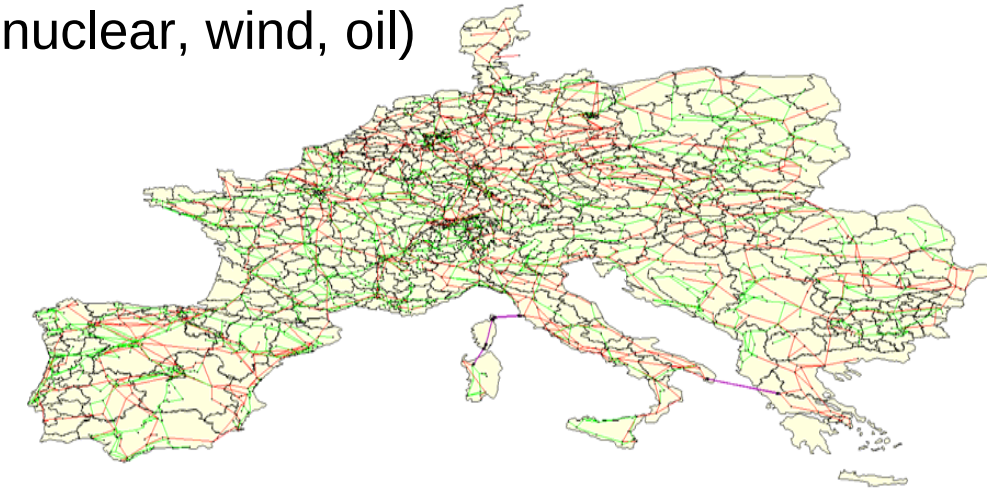
Database and market model



- Introduction
- Database and market model
- Load flow calculation
- Short-Circuit-Calculation
- Summary

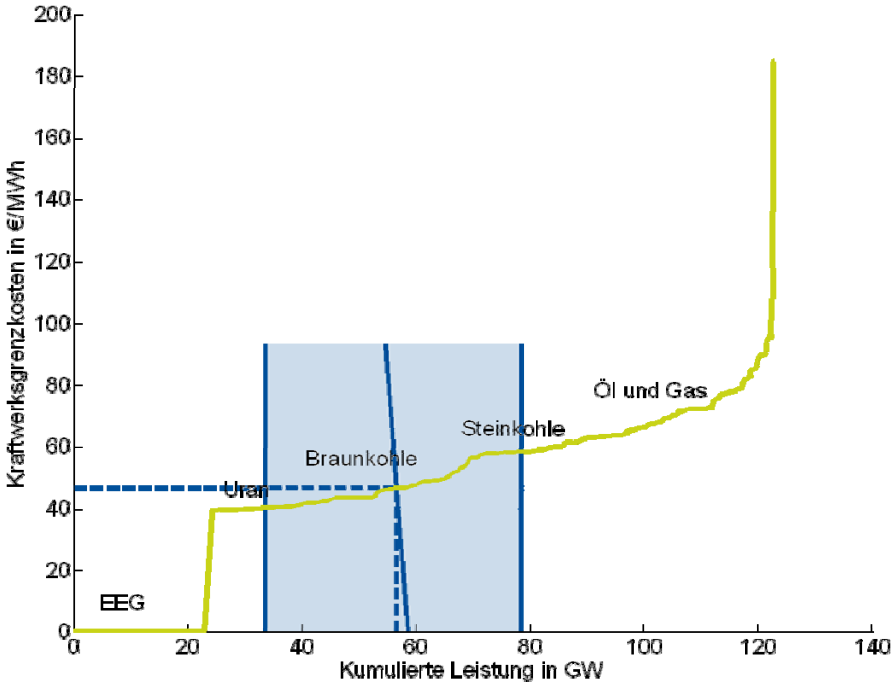
Database and market model

- Only publicly available sources used
- Load database
  - Time series for 21 different countries (former UCTE)
  - Population density for 418 european regions
- Power plant database
  - Approx. 2700 power plants
  - 14 different power plant types (e.g. wind turbine, CCHP, …)
  - 11 different fuel types (e.g. nuclear, wind, oil)
- Grid database
  - 220/380 kV voltage level
  - Approx. 3.000 nodes
  - Approx. 4.000 lines
  - Approx. 400 transformers
  - DC connections



Database and market model

- Market simulation is based on a merit order model
  - Power plants are sorted by their marginal costs and dispatched until load is covered
- Extended models are included to represent:
  - start-up costs
  - minimum shutdown time
  - minimal power infeed
  - grid congestions
  - cross-border trades
  - power plant outages
  - renewables
  - storage power plants



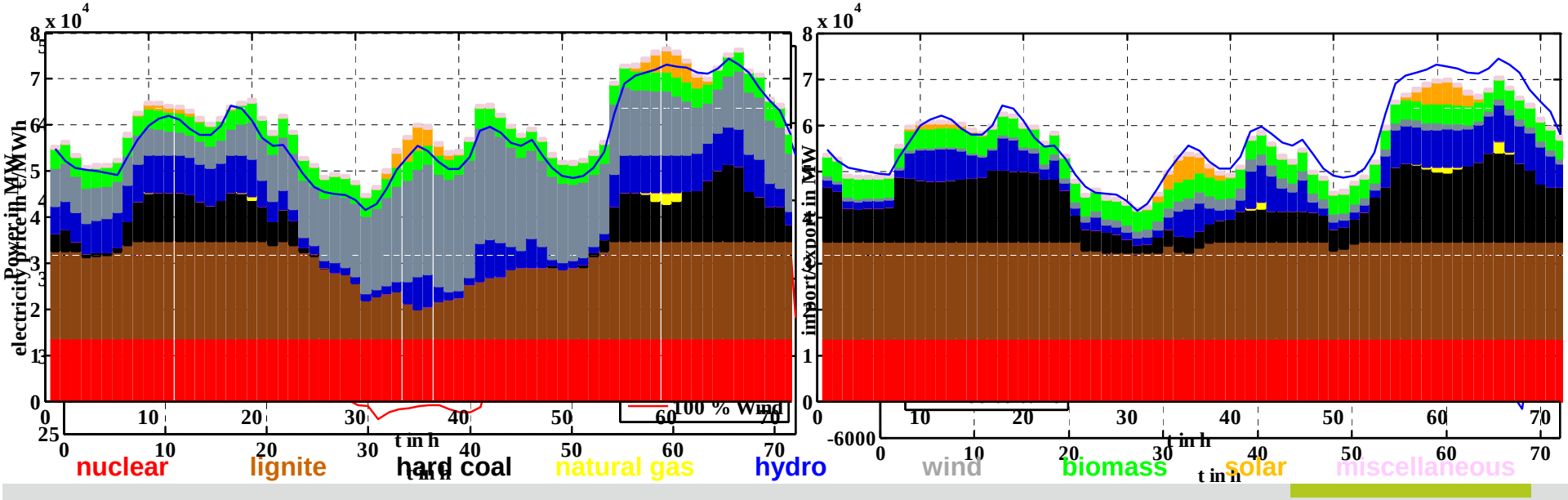
Influence of wind power on the electricity market

2 different scenarios:

- Installed wind power in Germany 28 GW Onshore, 2 GW Offshore
- scenario 1: 3 typical workdays, 100 % wind power
- scenario 2: 3 typical workdays, 10 % wind power

Influence of wind on the German electricity market

- conventional power plants are displaced by wind power
- lower wholesale price for electricity with 100 % wind power
- export of electricity only in case of high wind power infeed



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Load flow calculation

- Power plant schedules are used to do a load flow calculation

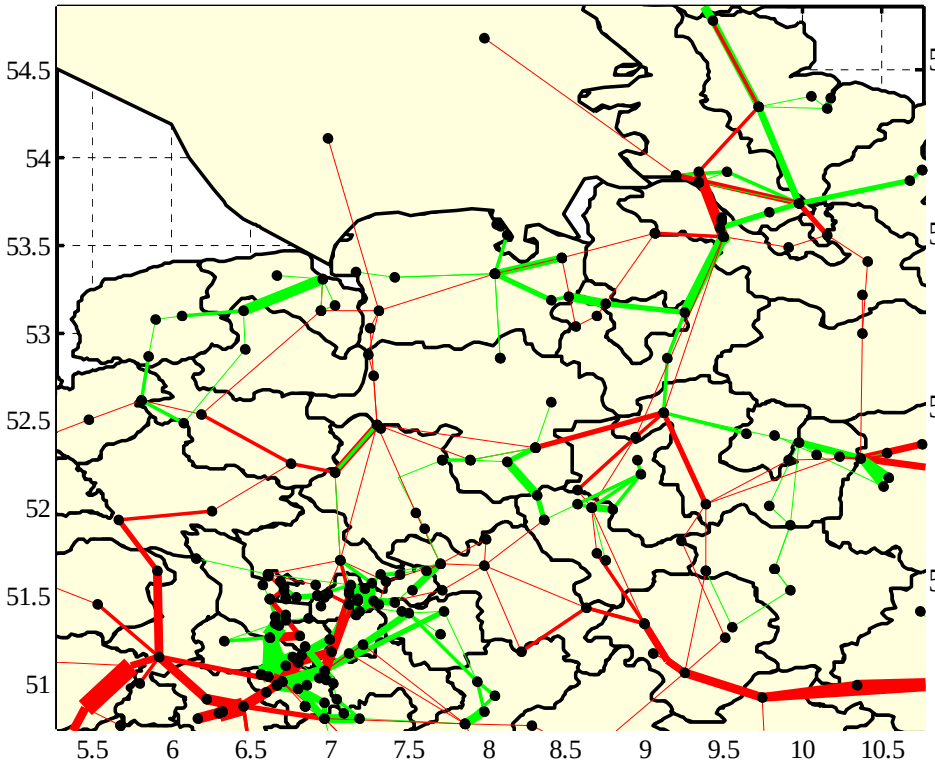
- Three different load flow models included:
  - **Newton-Raphson method**
  - Current iteration method
  - DC-loadflow

- Results of Newton-Raphson load flow:
  - Power flow
  - Nodal voltages
  - Line currents
  - Grid losses
  - Reactive power demand of the grid

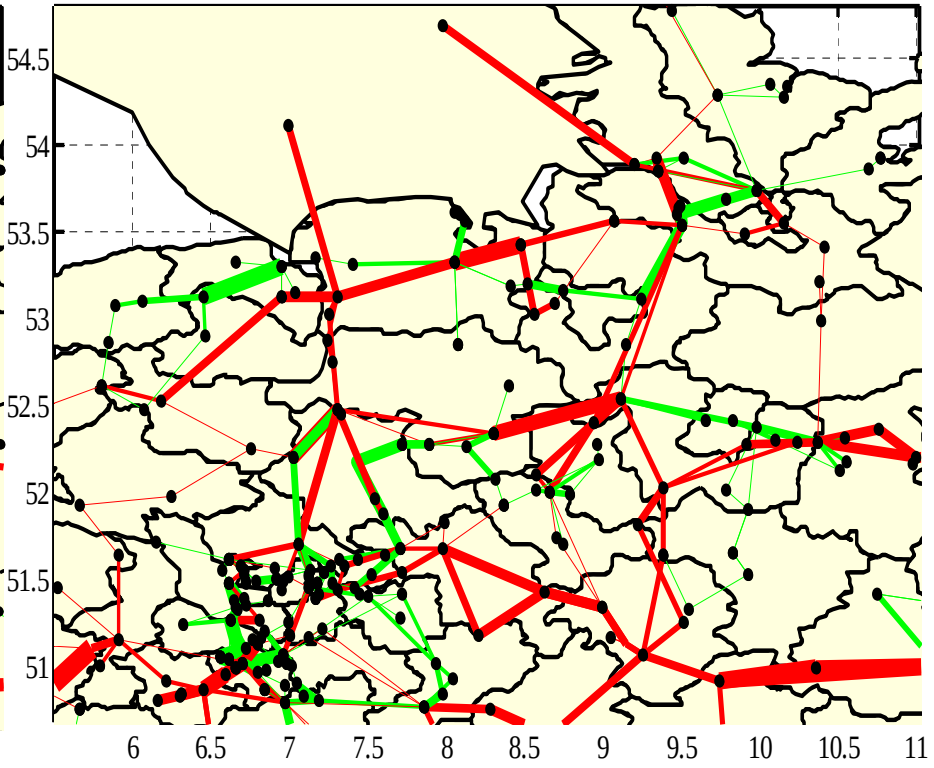
Influence of wind power on the load flow in Germany

Visualized power flow in northern Germany with two offshore wind farms of 1000 MW

10 % wind power infeed



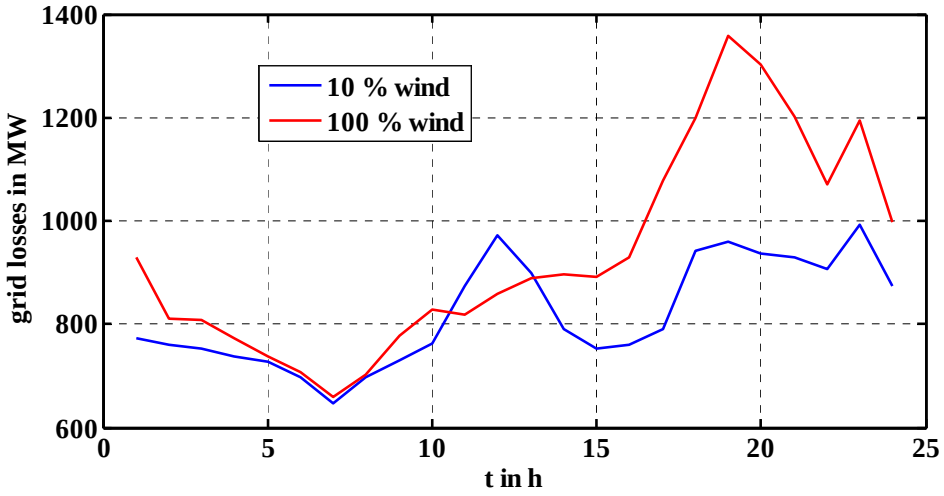
100 % wind power infeed

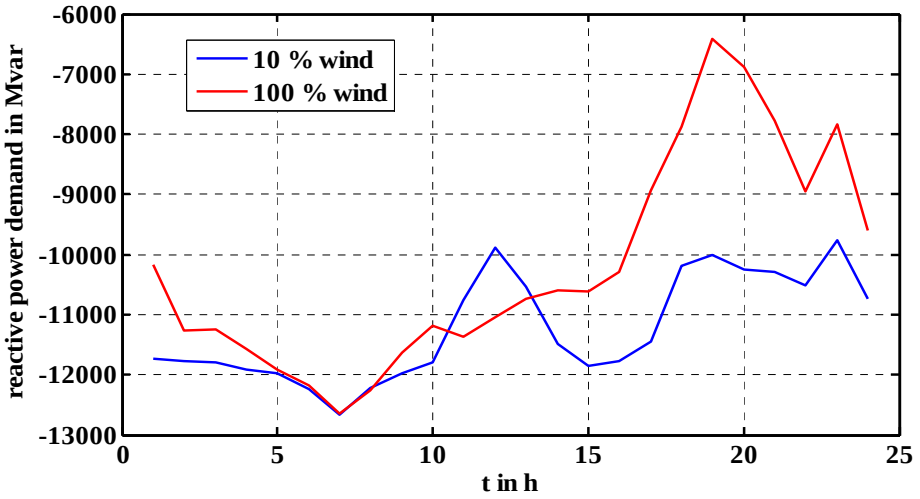


- Higher wind generation causes higher line utilization in northern Germany

Influence of wind power on the load flow in Germany

Losses and reactive power demand of the german grid





100 % Wind:
- Higher line utilisation
- Higher grid losses
- Lower reactive power demand

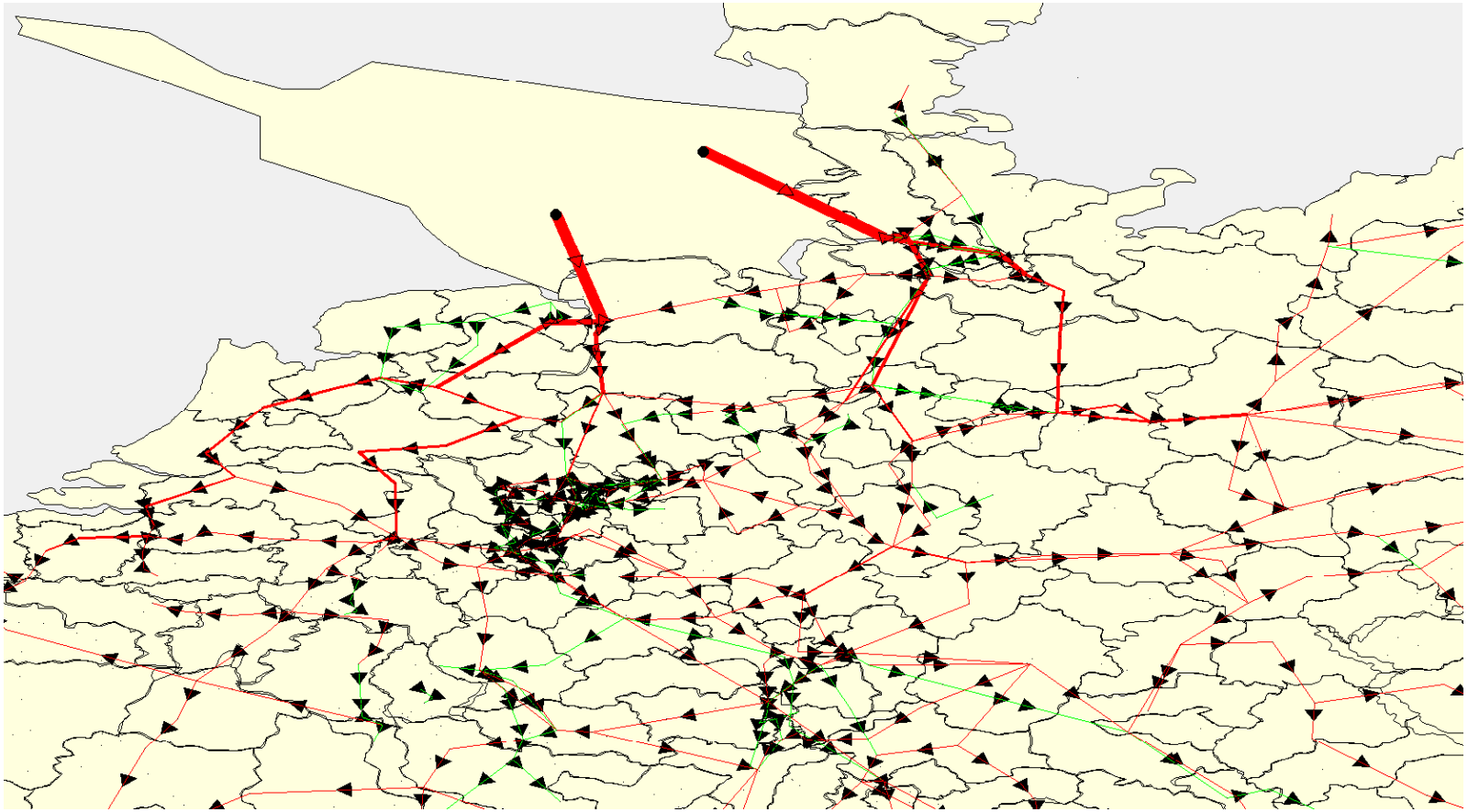
10 % Wind:
- Lower line utilisation
- Lower grid losses
- Higher reactive power demand

Load flow decomposition

- Decomposition of calculated load flow in the operating point using superposition method
  - Consideration of active as well as reactive power
  - Consideration of complex phase-to-earth impedances
- Analysis results:
  - Influence of reactive power infeed on nodal voltages
  - Influence of active power infeed on nodal angles
  - Influence of single power plants on transmission power of lines
- Scope of application:
  - optimization of grid losses and nodal voltages
  - optimal power plant redispatch in case of grid congestions
  - minimization of transits and loop flows
  - energy mix (nuclear, wind, solar,…) on lines and nodes

Influence of offshore wind farms on the European transmission grid

- Power flow decomposition for two offshore wind farms with 1000 MW



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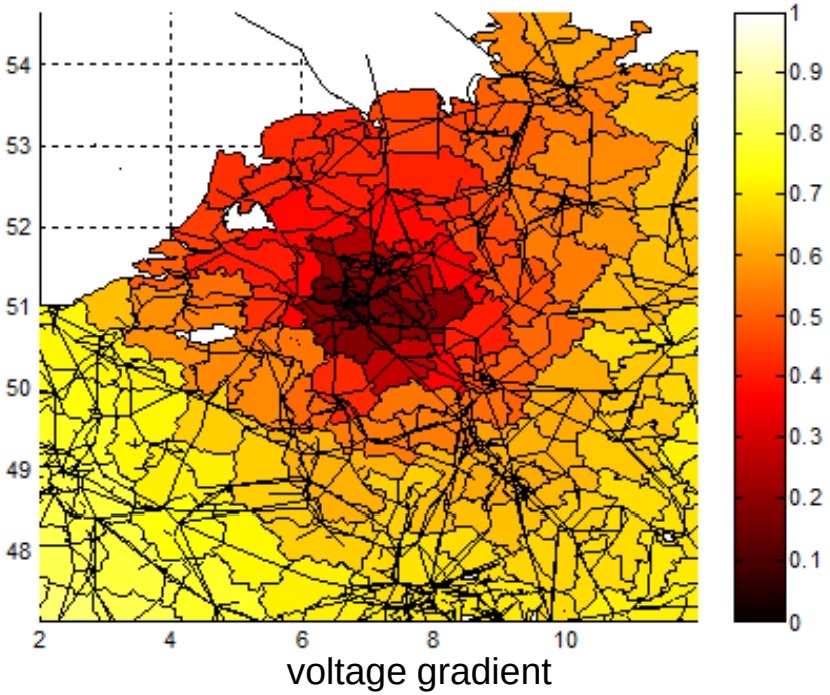
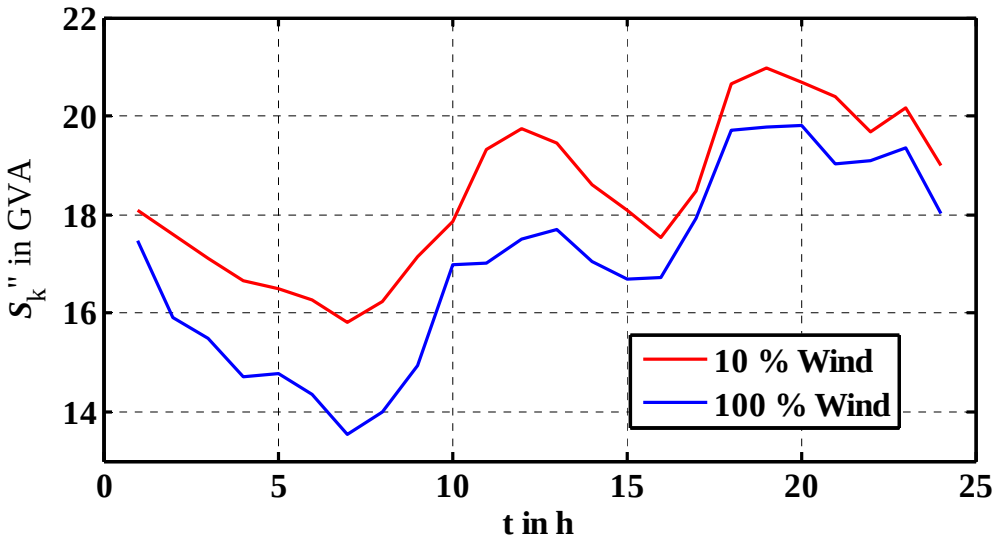
Short-Circuit-Calculation

Example: Three-phase short circuit in station Rommerskirchen



voltage gradient



short circuit power at Rommerskirchen

100 % Wind:
- Lower short-circuit-power
- Higher voltage gradient

10 % Wind:
- Higher short-circuit power
- Lower voltage gradient

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Summary

- Wind energy influences
  - Conventional power plant schedules
  - Exports and imports of electricity
  - Wholesale electricity prices
  - Load flow and line utilisation
  - Grid losses and reactive power balance
  - Short-circuit behaviour of the grid

- Combined grid and market analysis tool of Leibniz Universität Hannover is able to calculate the impact of these effects on the whole system

Thank you for your attention!

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