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Vulnerability of electricity transmission infrastructure to natural hazards

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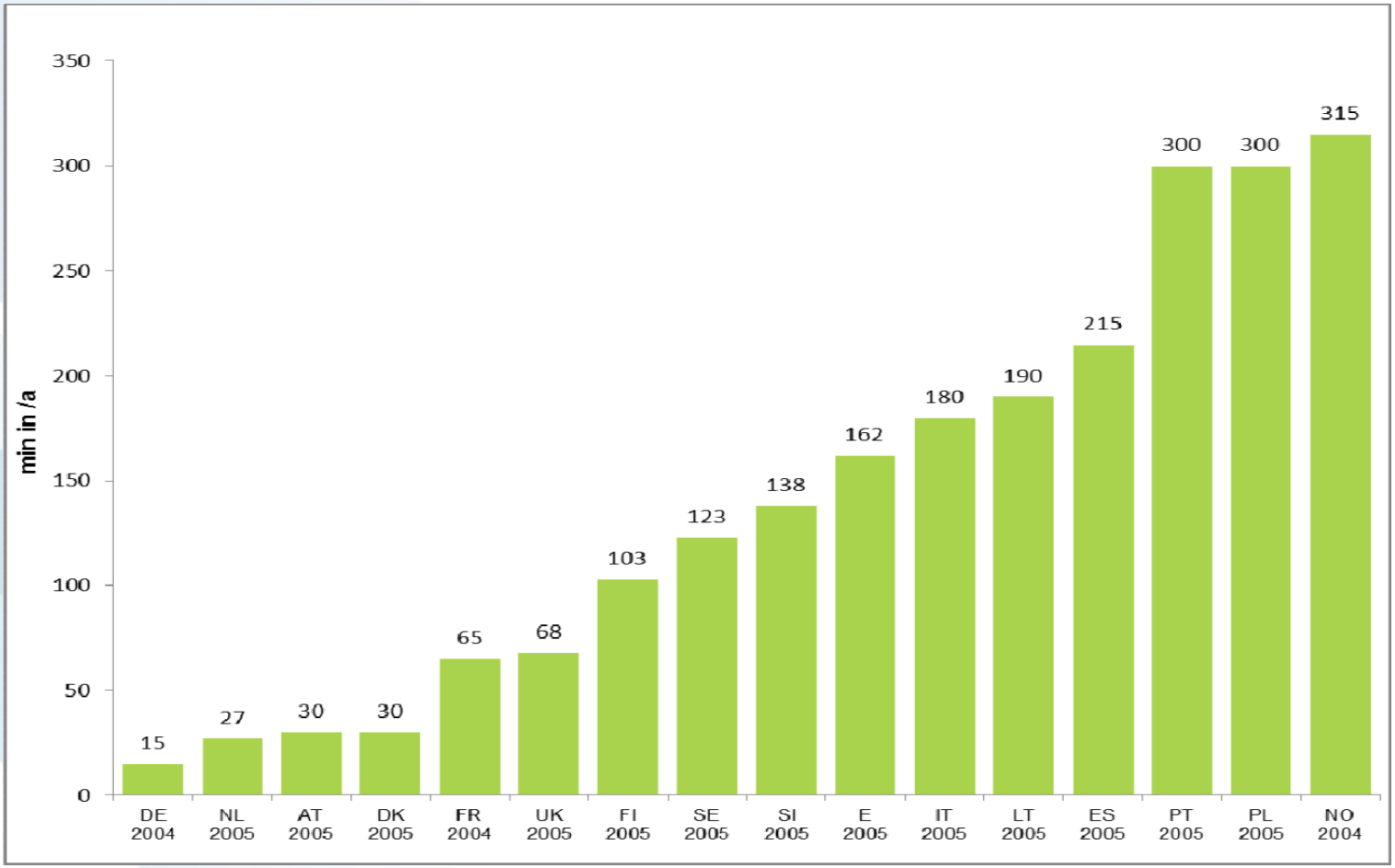
EGU: NH9.1: Natural hazard event analyses for risk reduction and adaptation

Vienna, 19 April 2016

Number of major blackouts is raising

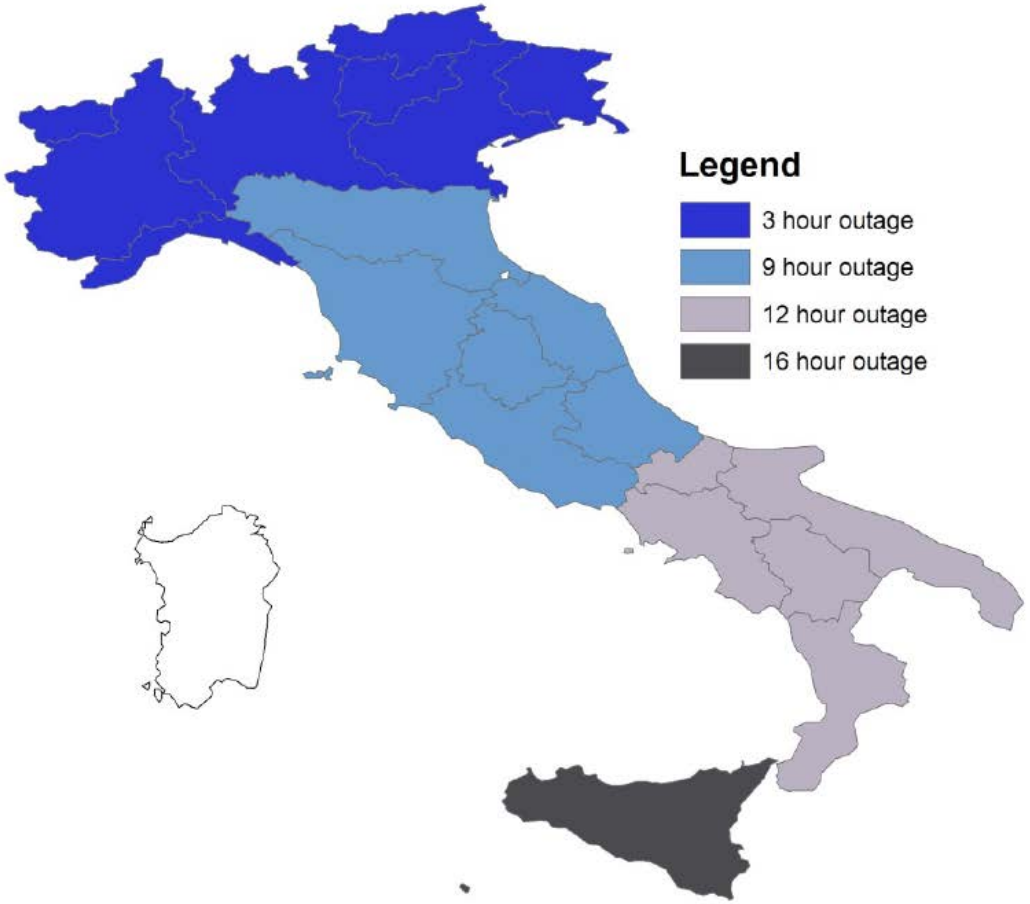
Location	Millions of people affected	Date
India	670	30-31 July 2012
Indonesia	100	18 Aug. 2005
Brazil	97	11 Mar. 1999
Brazil, Paraguay	87	10-11 Nov. 2009
United States, Canada	55	14-15 Aug. 2003
Italy, Switzerland, Austria, Slovenia, Croatia	55	28 Sep. 2003
United States, Canada	30	9 Nov. 1965

Number of frequent blackouts is raising: per capita average minutes without electricity in Southern and Eastern Europe



Source: CEER (2005/2008)

2003 blackout in Italy and Switzerland affected 56 million people

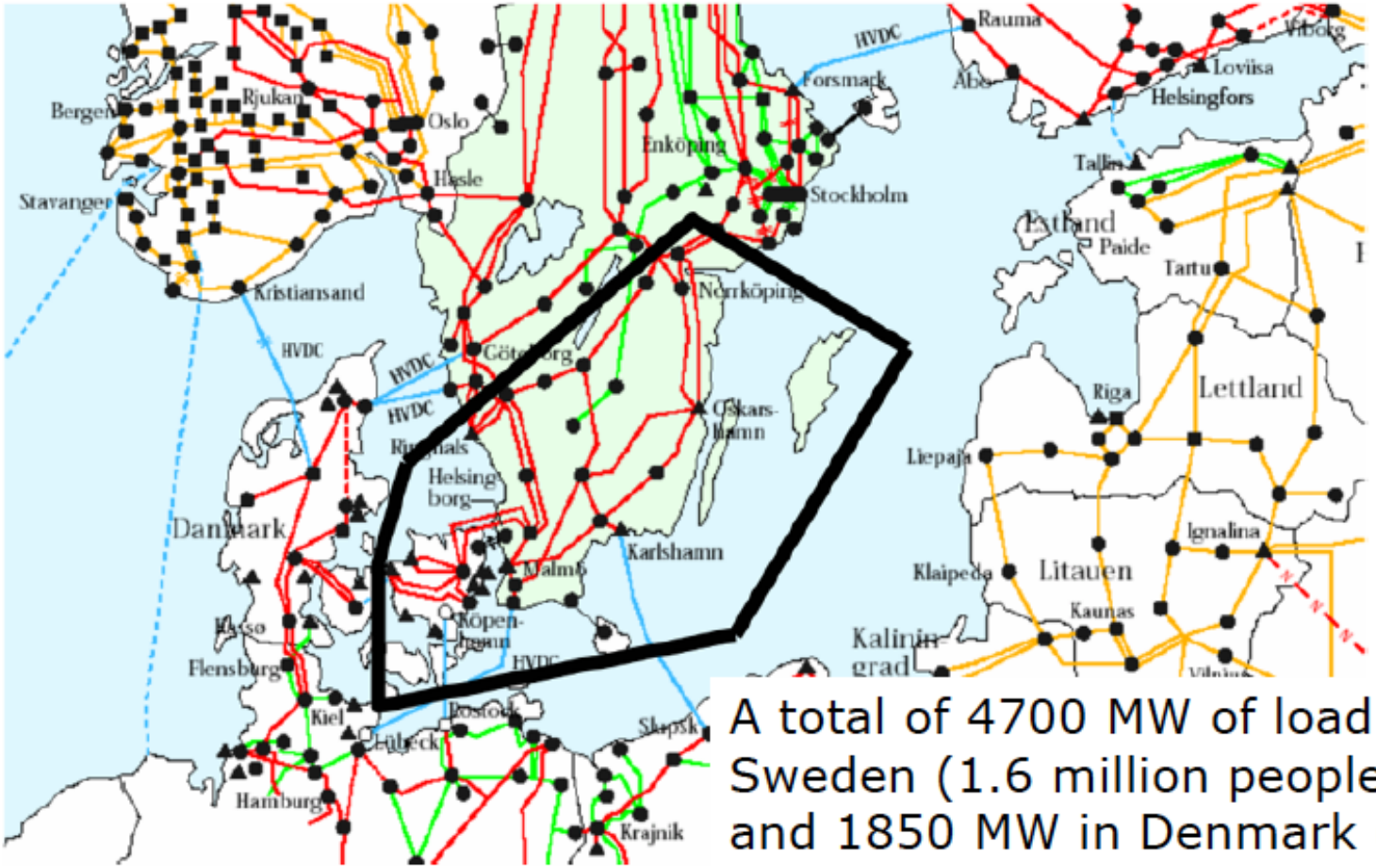


Overload of 380kV line between Mettlen and Lavorgo = raise of core temperature of the grid = affected nearby trees = flashover

- Failure of Mettlen-Lavorgo resulted in increasing loading of 380 kV Sils-Sosa line
- Domino effect from Swiss line put the Italian line out of synchronization with the Union for the Cooperation of Transmission of Electricity (UCTE)

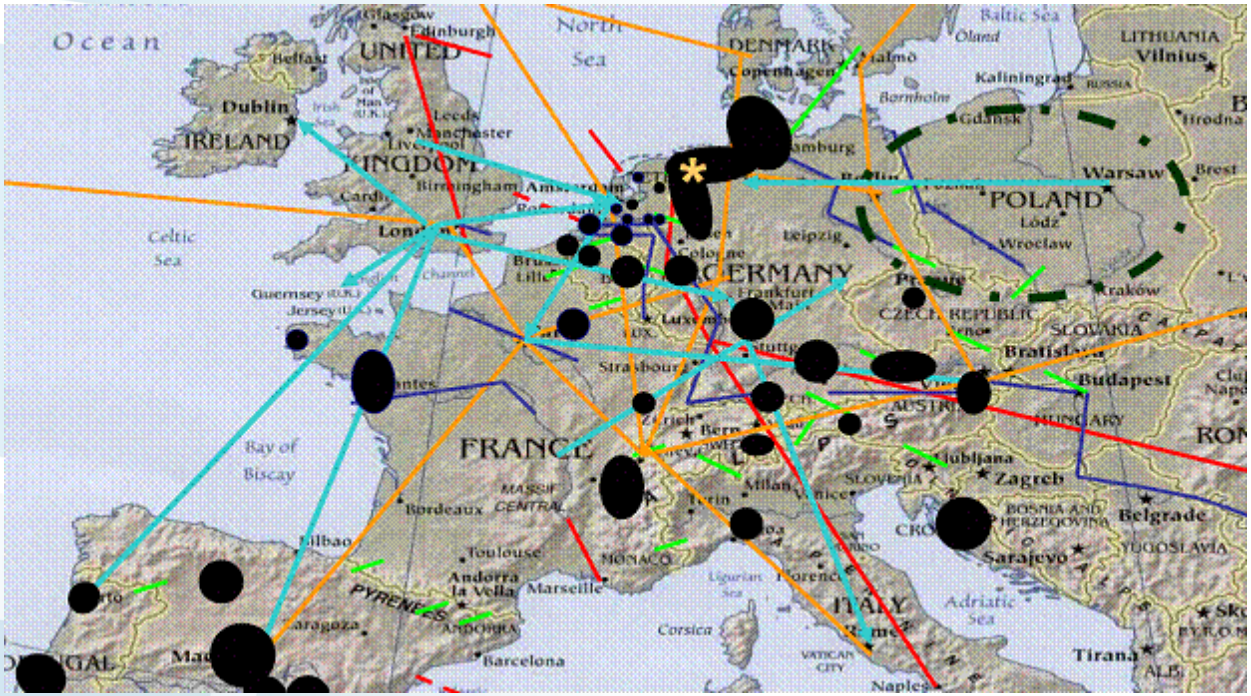
Area affected by Swedish-Danish Blackout on 23 Sept. 2003

The grid separation at 12.37



A total of 4700 MW of load was lost in Sweden (1.6 million people affected) and 1850 MW in Denmark (2.4 million people affected).

2006 blackout in Germany



- German TSO E.ON Netz had to switch off a high voltage line to let a ship pass underneath.
- Simultaneously there was a high amount of wind electricity which fed into the grid 10,000 MW from wind turbines to Western and Southern Europe grids.

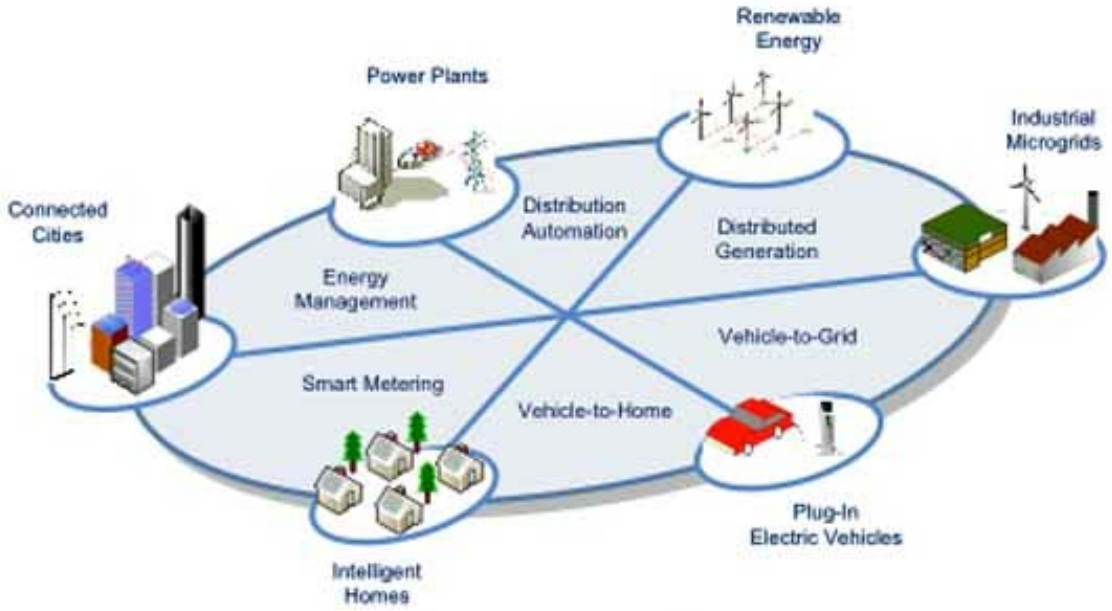
- Insufficient communication about this switch-off led to instabilities of the frequency in the grid and to overloading of lines.
- Devices had to switch customers off in the countries affected to cope with this lack of power in the Western zone automatic.
- The blackout lasted up to two hours.

Factors influencing vulnerability of electricity grids

- New requirements
- State of electricity infrastructure
- Barriers for upgrading of the system
- Existing interdependencies
- Multiple risks

1. New requirements on grid architecture and increased vulnerability

- Designed 50 years ago to satisfy needs with generating plants located near load areas
- Diversification of electricity supply located in different areas



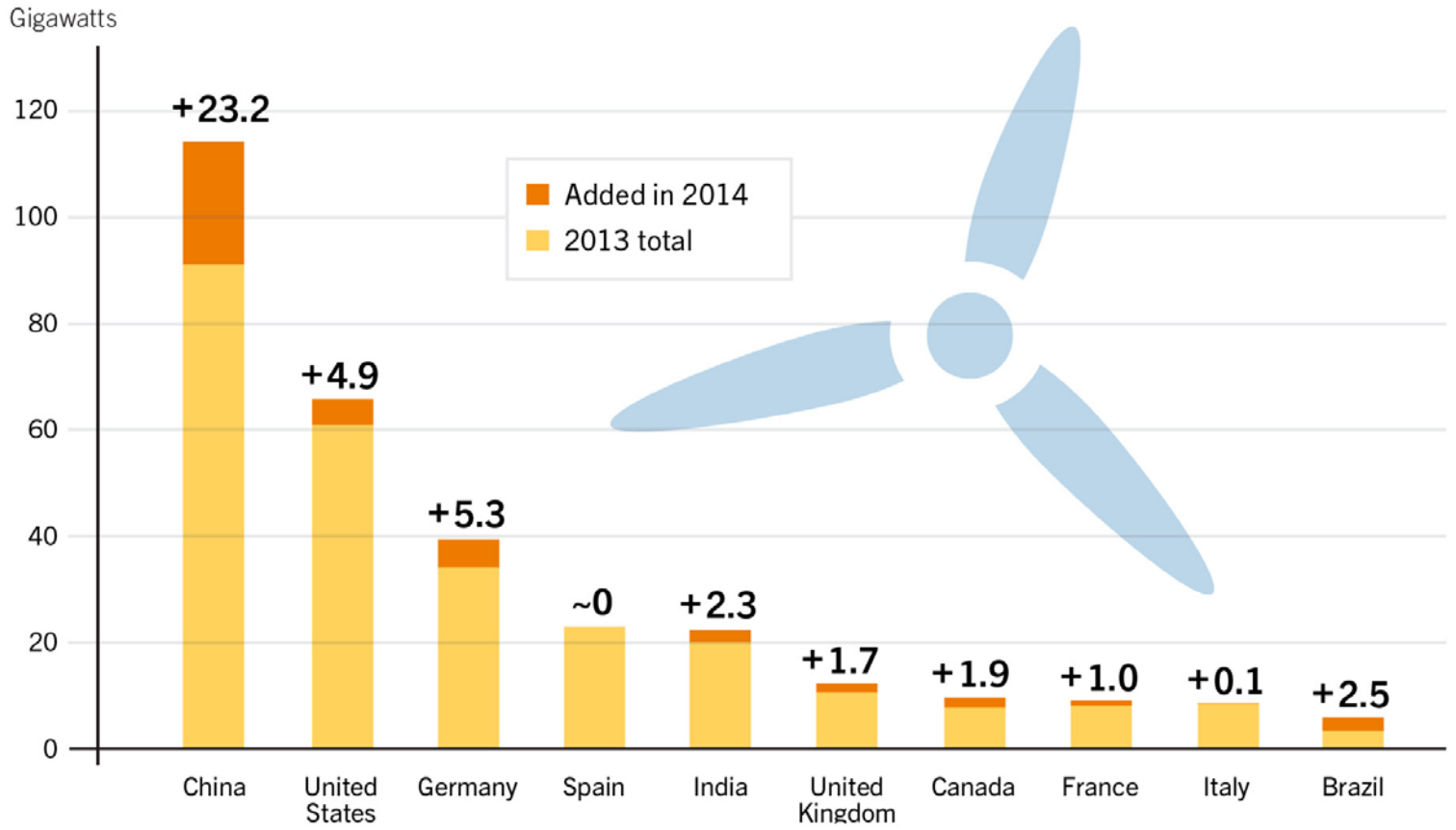
Smart Grid building blocks

Grids at the border of their capacity to integrate growing volumes of renewable energy electricity (EWEA, 2005)

Several new km need to be constructed to secure market integration, security of supply and accommodate renewable energy expansion (ENTSO-E, 2010)

Challenges of energy transition

Wind Power Capacity and Additions, Top 10 Countries, 2014



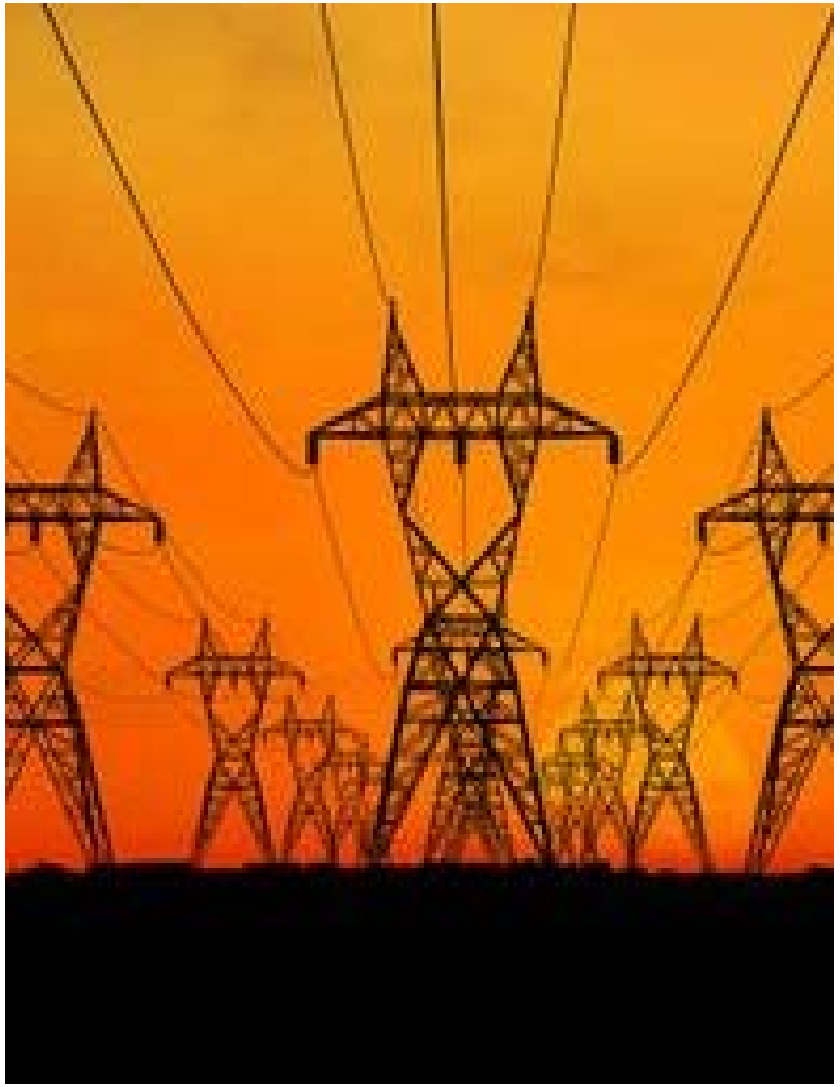
Additions are net of repowering.

REN21 *Renewables 2015 Global Status Report*

REN21 Renewable Energy Policy Network for the 21st Century

2. Current situation in transmission networks and increased vulnerability

- Majority of grids is 30-40 years old (Ecofys, 2008)
- Cross-border interconnectors (Battaglini, 2009)
- In some countries no single line at voltages higher than 200 kV was constructed during the last 10 years (ETSO, 2006)
- Distribution lines

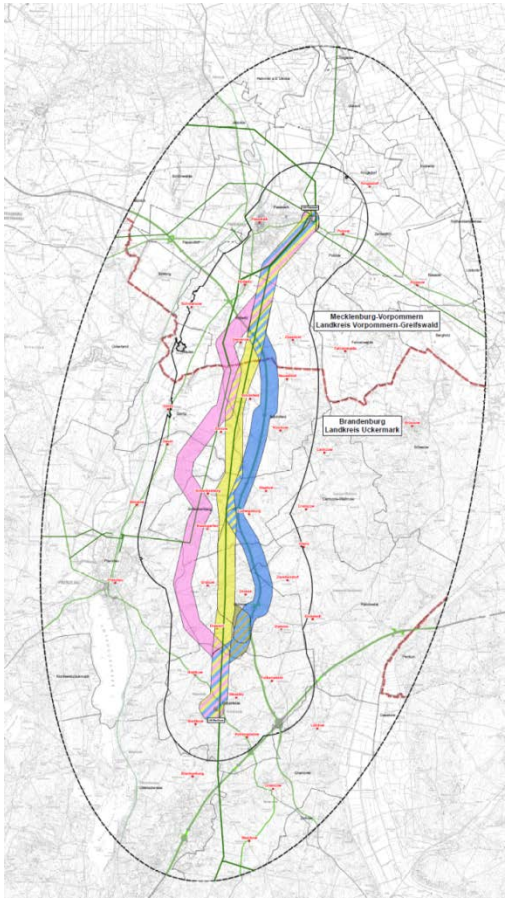


3. Public acceptance as a bottle neck

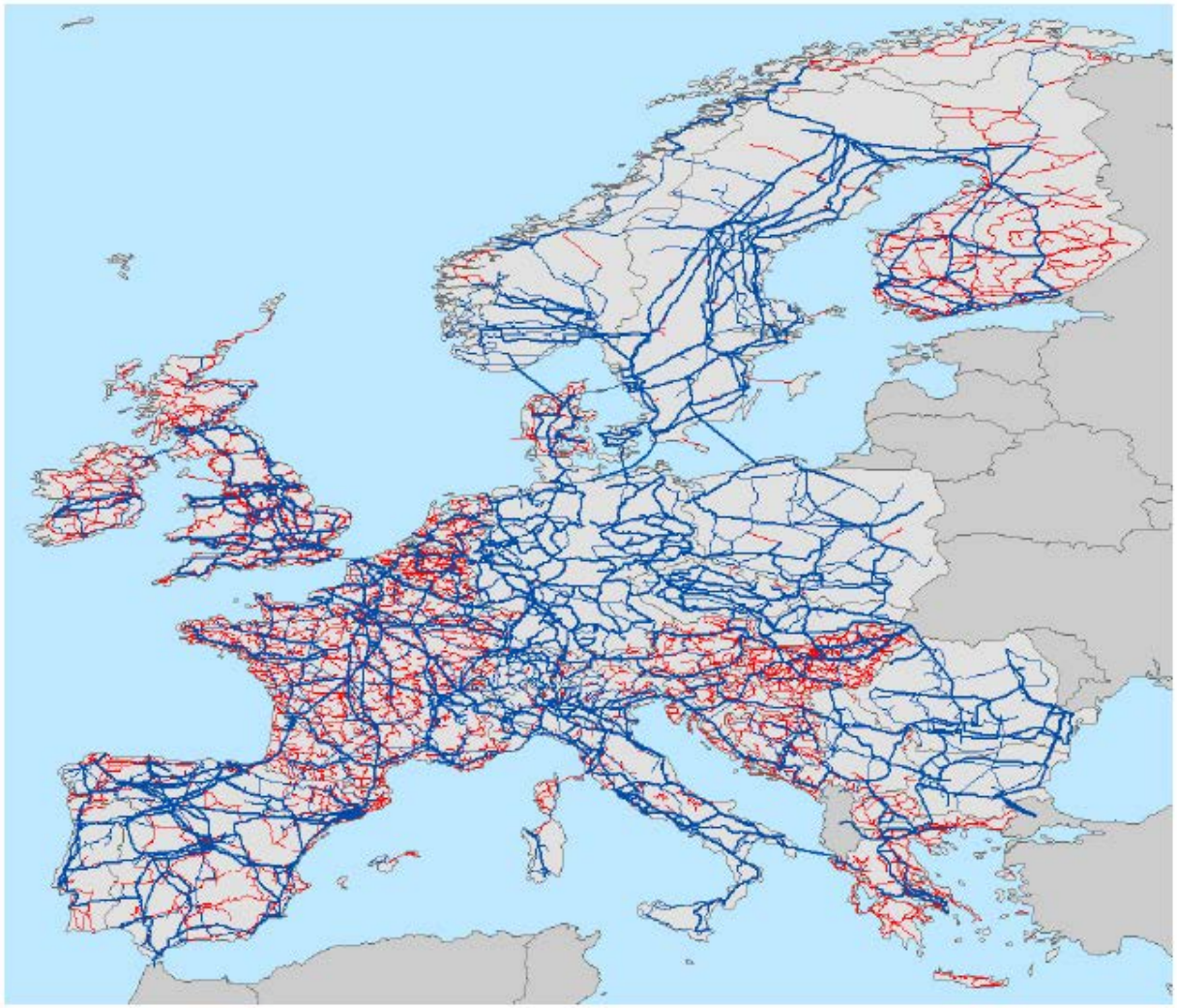
Source: BESTGRID Project

Two projects in Germany

- TenneT, SUED.LINK, 800 km power line to deliver 4GW from generation in North to consumption in South of Germany
- 50Herzt, 380kV line between Bertikow in Brandenburg and Pasewalk in Mecklenburg-Vorpommern.



4. Vulnerability of electricity lines in Europe is affected by interdependencies between different systems and potentials for cascading effects



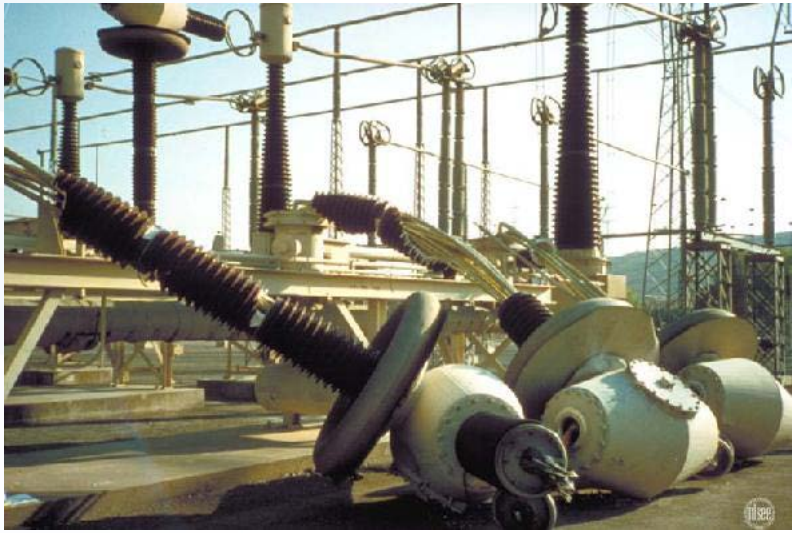
The European high voltage transmission grid, composed of lines with a voltage greater or equal to 220 kV.

High voltage lines are in blue.

Low voltage lines are in red.

Source: Poljanšek et al., 2012

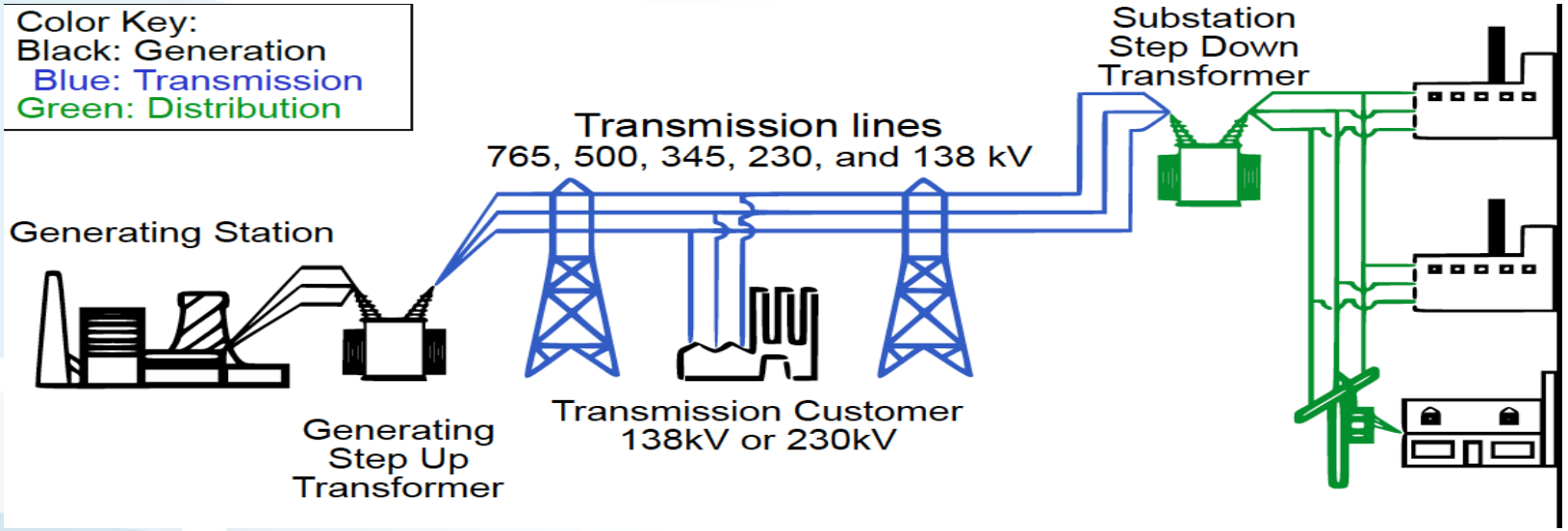
Complexity of the electricity transmission system



Effects of earthquakes on transformers

Effects of flooding on distribution station and pylons

6. Interdependency of factors affecting vulnerability of electricity lines



- Failures in distribution grids (non redundant design)
- Deviations from planning criteria due to events which were not considered in grid planning for economical reasons
- Human failures
- Forecast errors for renewable energy resources
- Impacts of severe weather events
- Emerging threats of cyber and terrorist attacks on grid infrastructure

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