

Towards Analysis & Simulation of Future Networks

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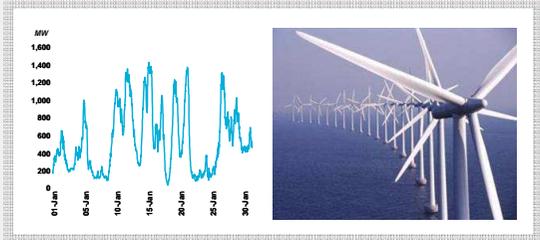
Overview

- Future networks
 - The transmission challenge
- System Operation and Planning
 - Future analysis requirements
 - System integration & automation
 - Network development: the German case
- Multiterminal HVDC grids
 - Solution for pooling renewable energy
- Conclusions

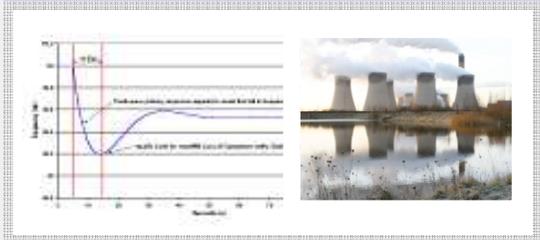


The Transmission Challenge

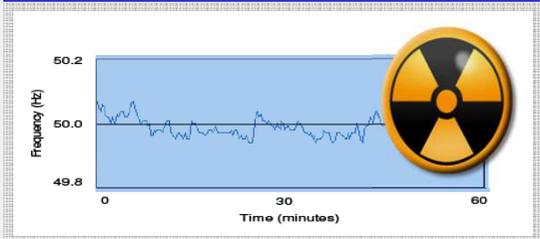
Variable generation



Large generation



Inflexible generation



Smarter transmission network



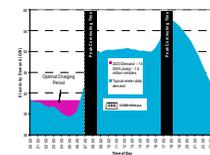
- **System operation**
 - Optimized operation close to real time
 - Efficiently and accurately create the required system configuration
 - Increased data volume
- **System planning**
 - Efficient use of existing transmission capacity (getting closer to technical limits)
 - Investment in new transmission assets

Active distribution networks



Smart grids & meters, energy storage

Active demand



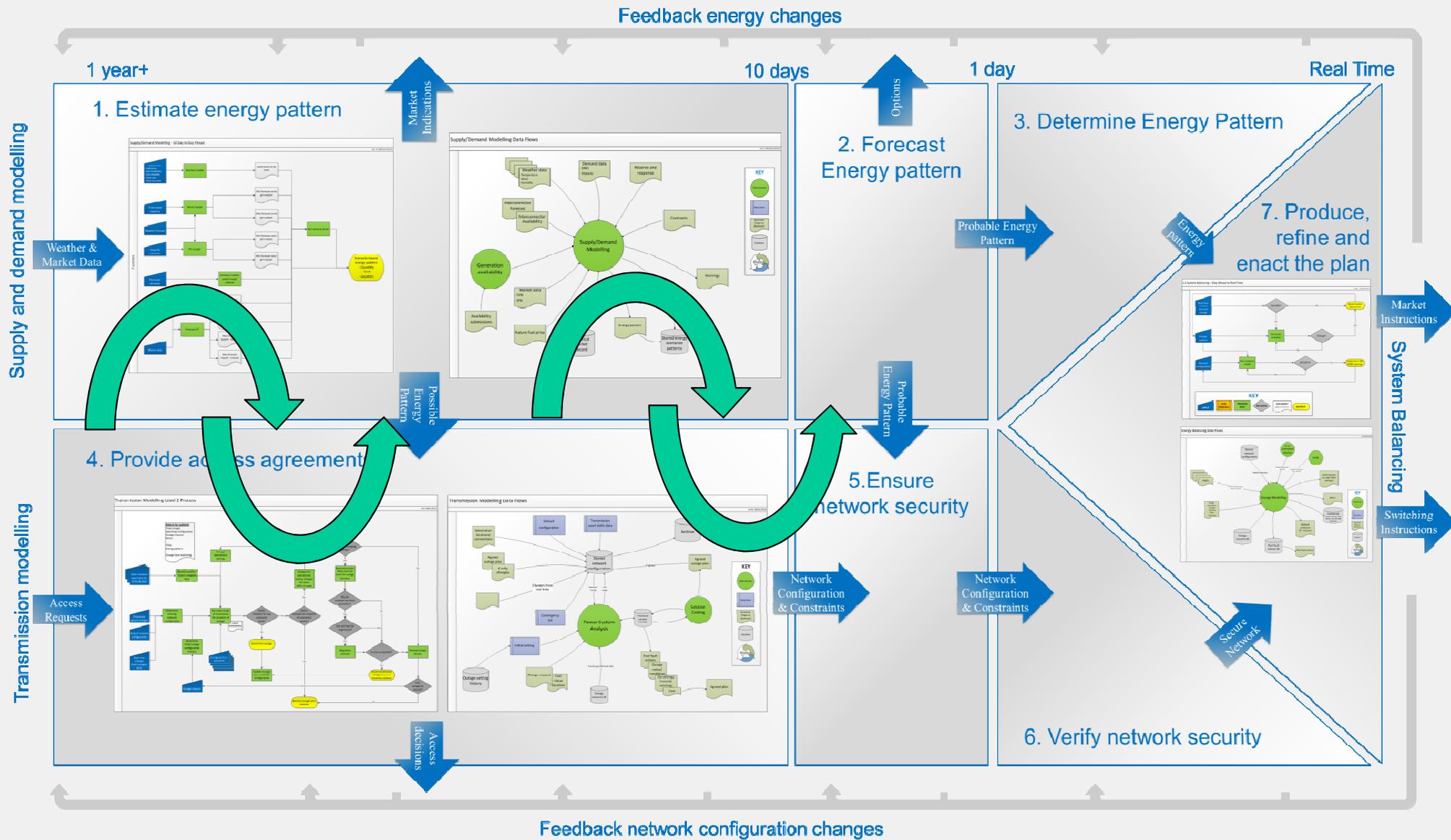
Time of use tariffs

Distributed generation



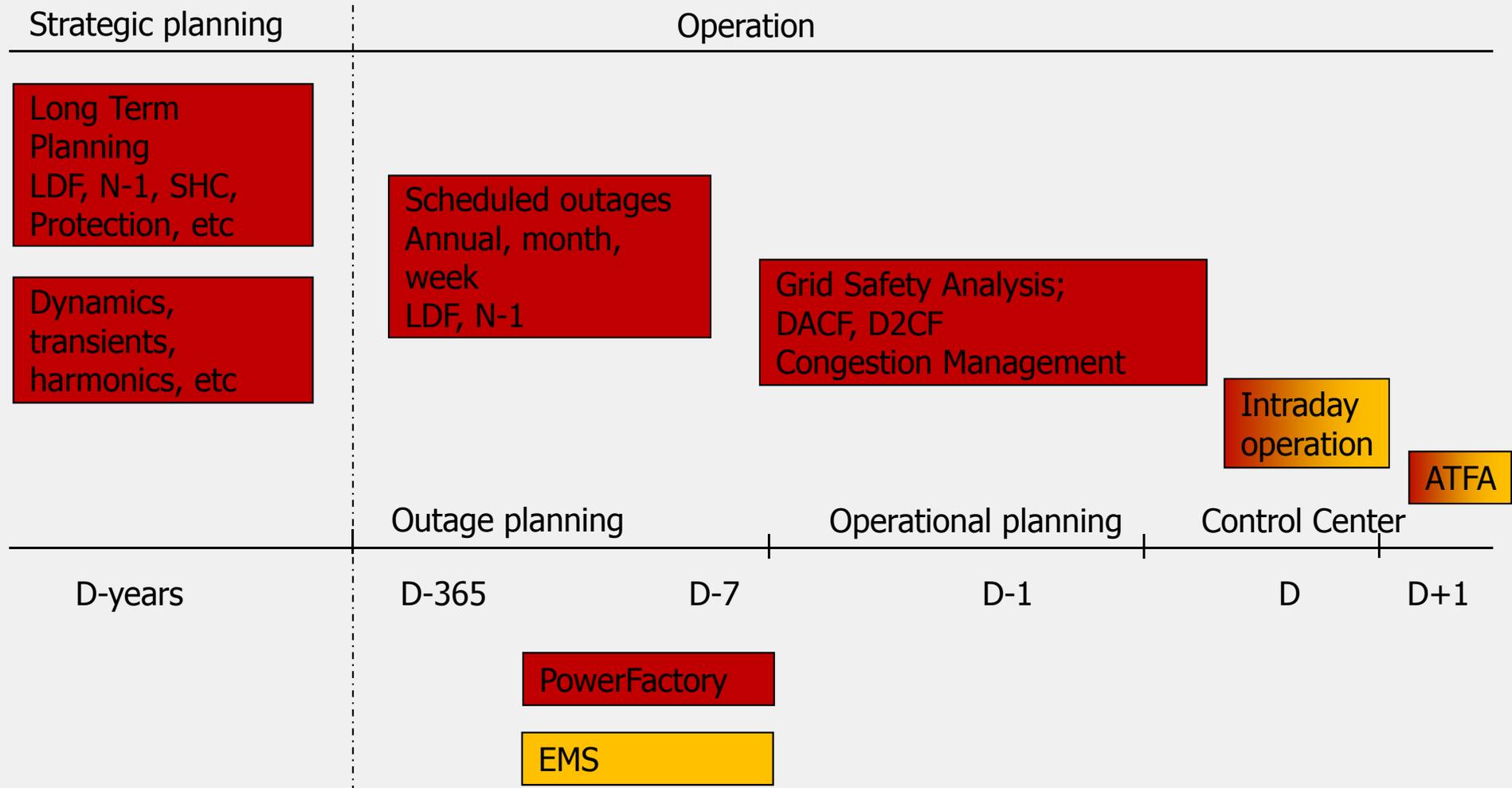


The future system operation



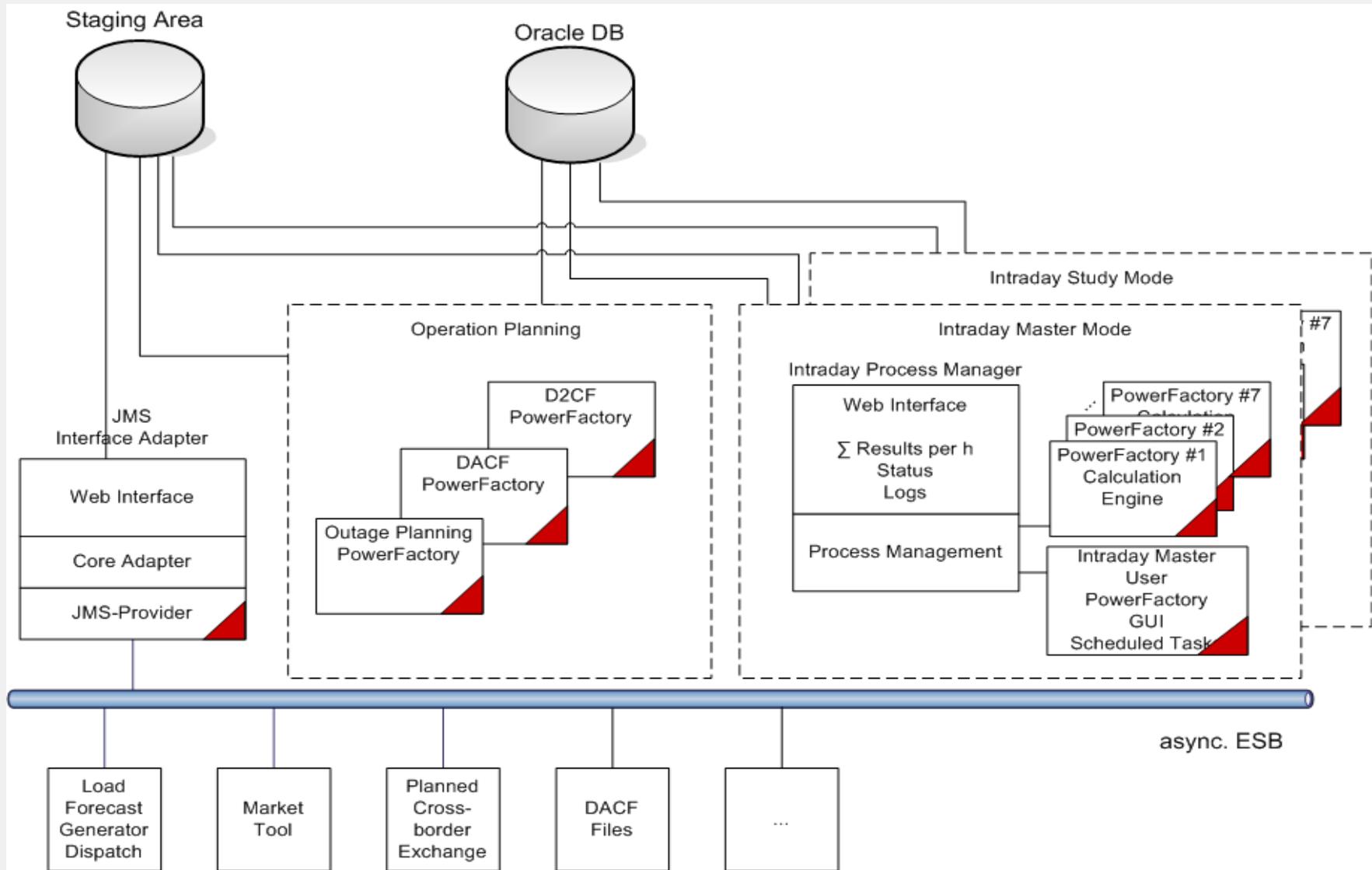


Increased needs for detailed network analysis





Architecture solution





Automated processes and parallelization

- Parallel calculation of scenarios (engine manager)
 - Increased number of scenarios (time points) due to higher contribution of non-dispatchable generation (renewables)
- Status and result display
 - Summary results, also as web service

Intraday Summary Report Restart Se...

Running...

Day_Hour	Project Activation	CTDS-Import		IET-Import		TPrognosis-Import		Outage Apply	Load Flow Calculation						IDCF-Export		
	(status)	(status)	Date	(status)	Date	(status)	Date	(status)	(status)	Equipment Name	Loading [%][A]	Equipment Name	Min. Voltage [%]	Equipment Name	Max. Voltage [%]	(status)	(status)
Mon 3_04	✓	✓	2013-01-28 14:46	✓	2013-01-28 14:46	✓	2013-01-28 14:46	✓	✓	BS30 Iijn	73,25	[Veenoord 110] B	0,00	[Terneuzen Zuid 50_A] B	109,18		⌛
Mon 3_08	✓	✓	2013-01-28 14:46	✓	2013-01-28 14:46	✓	2013-01-28 14:46	✓	✓	HW-VLN150 W	85,11	[Veenoord 110] B	0,00	[Terneuzen Zuid 50_A] B	107,36		⌛
Mon 3_10	✓	✓	2013-01-28 14:46	✓	2013-01-28 14:46	✓	2013-01-28 14:46	✓	✓	HW-VLN150 W	94,10	[Veenoord 110] B	0,00	Bkl 50kV	108,33		⌛
Mon 3_11	✓	✓	2013-01-28 14:46	✓	2013-01-28 14:46	✓	2013-01-28 14:46	✓	✓	HW-VLN150 W	92,55	[Veenoord 110] B	0,00	Bkl 50kV	108,04		⌛



Network Planning



Optimization of existing transmission network

- Dynamic circuit ratings, short term ratings
- Extensive use of post-fault actions as a way to secure network operation under (n-x) contingencies
- Phase shifters, optimization of tap positions
- Wide-area monitoring, dynamic stability assessment

Consider short term ratings

Short term ratings [MVA]:

	360min	20min	10min	5min	3min
▶ 30,00%	2210,	2610,	3240,	4310,	5510,
60,00%	2210,	2510,	2980,	3810,	4750,
75,00%	2210,	2420,	2780,	3410,	4150,
84,00%	2210,	2370,	2630,	3110,	3680,

Method

Multiple Time Phases

Base Case versus Contingency Load Flow

- Use same settings
 Allow different settings

Calculation Settings

Load Flow

... Load Flow Calculation

Time Phase 1 3. min



Time Phase 2 10. min



A Method

- AC Optimization (Interior Point Method)
 DC Optimization (Linear Programming (LP))
 Contingency Constrained DC Optimization (LP)

Contingency Analysis

... WP Yr7 High Wind\High Wind

Objective Function

Min. Transformer Tap Change (Pre-to-Postfault)

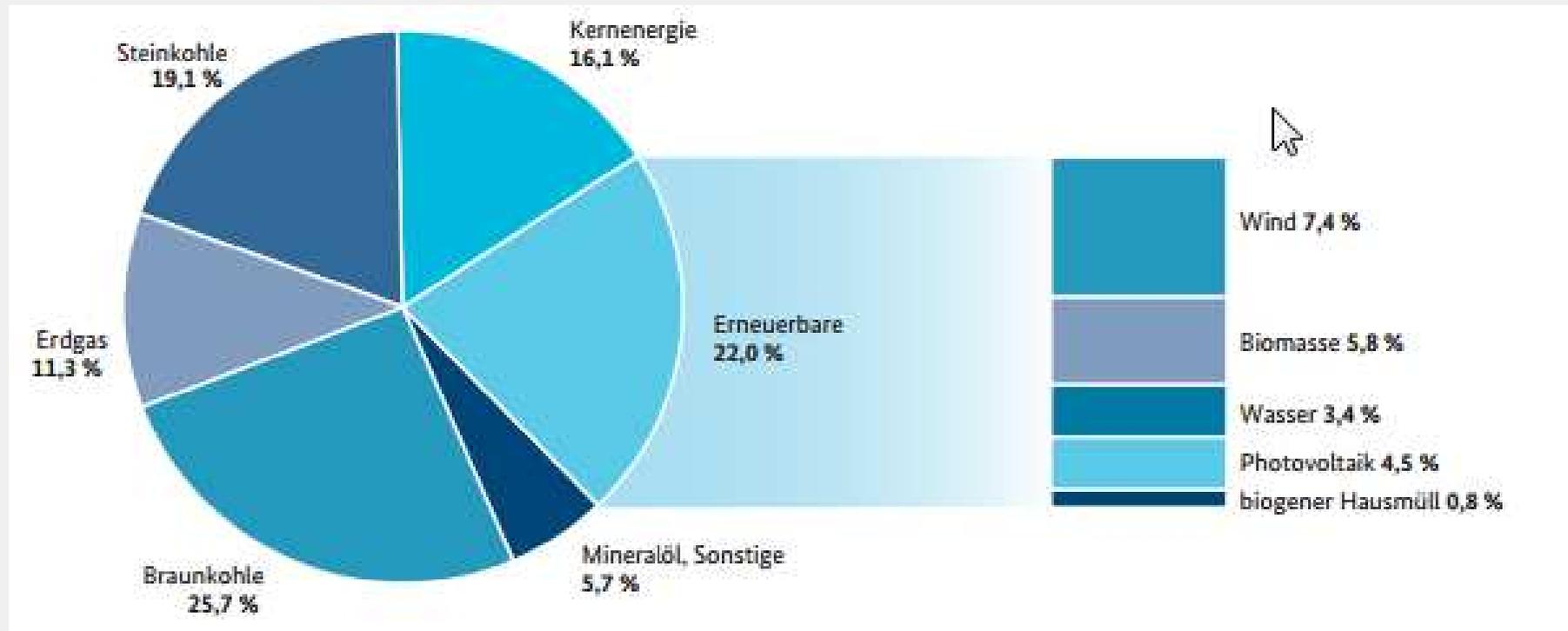


Increase of transmission capacity

- Investments in new transmission assets
- Flexible ac transmission systems (FACTS)
 - Series compensation (detailed SSR studies, protection coordination)
 - STATCOMs, MSCs, etc.
- AC to DC line conversion
- HVDC links to reinforce the transmission backbone or to connect offshore renewable resources to the onshore network
 - Optimal power flow including HVDC technologies



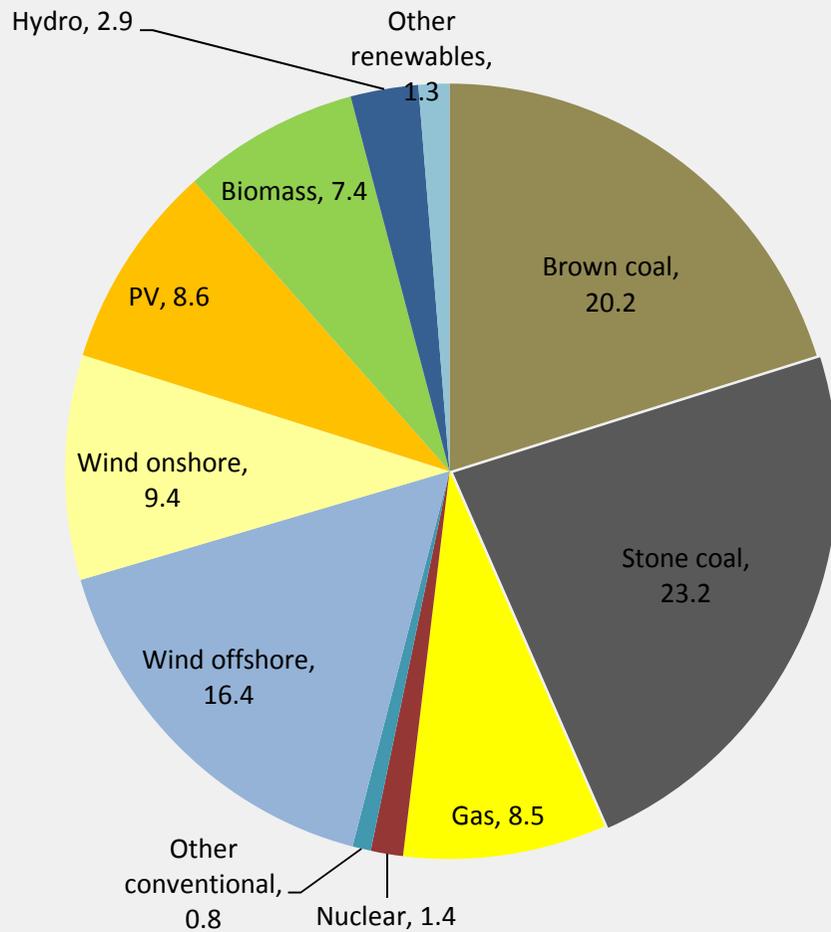
The German case



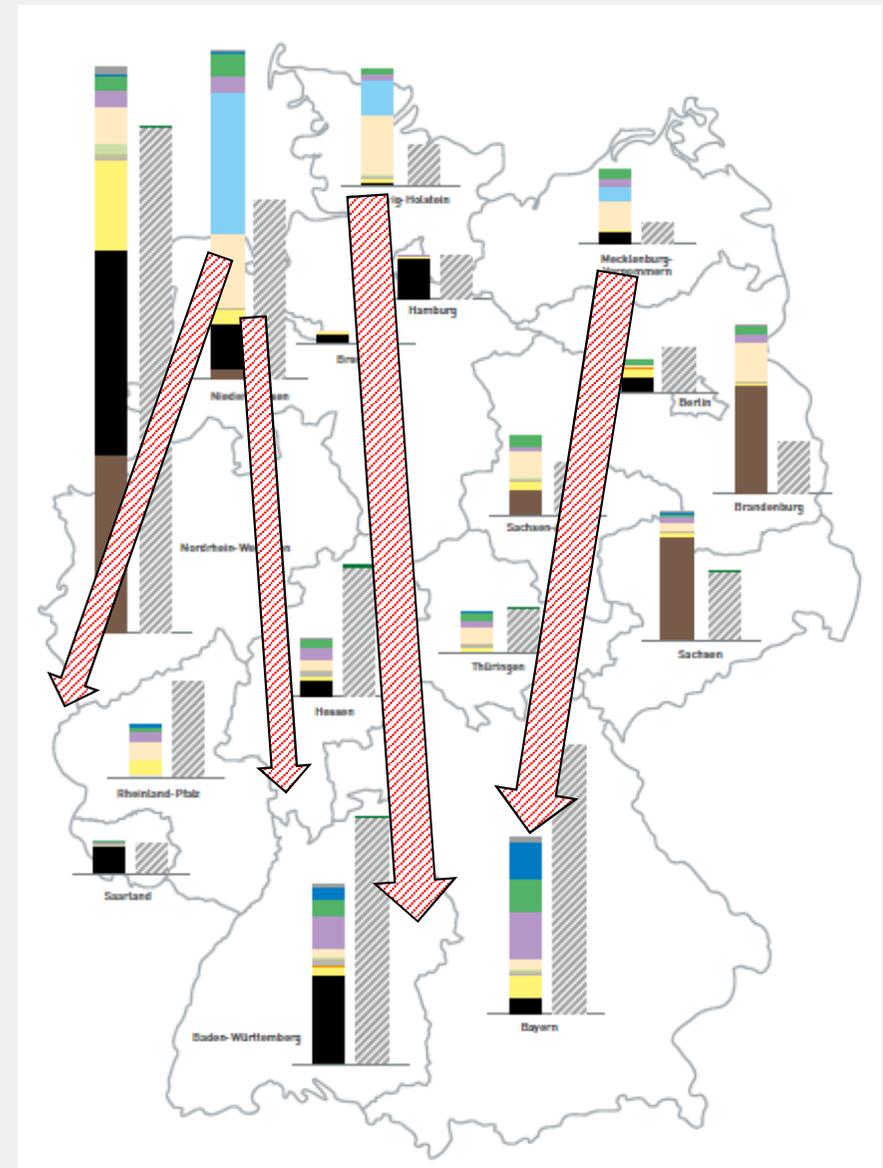
- Shut down all nuclear power plants by 2022



The German case: scenario 2023



Totals: **Generation: 650 TWh**
 Demand: 570 TWh
 Export: 80 TWh (~12% of gen.)





Grid Expansion Plan (Scenario 2023)

- New connections:
 - 4 HVDC corridors north-south with a transmission capacity of 12 GW, total length of about 2100 km
 - 1500 km of new AC grid connections
- Reinforcement of existing connections:
 - About 3400 km of new AC lines in existing traces
 - About 1000 km line re-conductoring
 - Conversion of about 300 km of existing AC lines to DC
- Total investment in grid expansion ~ 22 billion € (in the next 10 years)



Offshore Grid Expansion Plan (Scenario 2023)

- Offshore grid, scenario 2023
 - 14.1 GW offshore wind power (North Sea 12.8 GW, Baltic Sea 1.3GW)
 - Overall length of the extension of the offshore grid amounts to around 2115 km:
 - 1705 km of DC grid connection systems in the North Sea
 - 410 km of AC grid connection systems in the Baltic Sea
- Total investment in offshore grid expansion amounts to around 22 billion € (in the next 10 years)

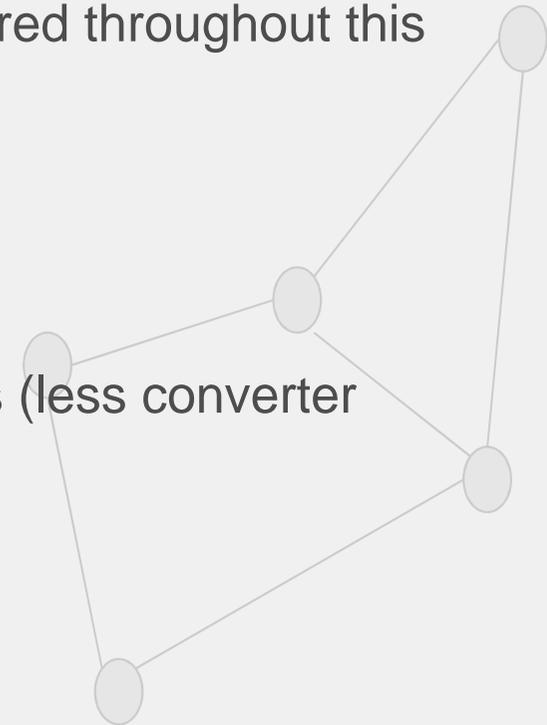


Multiterminal HVDC Grids



Multiterminal HVDC grids

- Solution for pooling renewable energy (hydro, solar and wind) and transmitting it to load centers
 - In Europe revived interest to integrate offshore wind farms in the North and Baltic see.
 - Supergrid connecting Europe, the Middle East and North Africa to allow sharing of the hydro, wind and solar resources scattered throughout this vast area (DESERTEC project)
- Some of the advantages of dc grids
 - Redundancy in dc links (meshed dc topology)
 - Number of converters is less than the number of links (less converter losses and capital costs for converters)





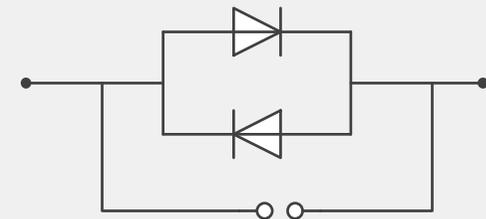
Multiterminal HVDC grids

- Voltage source converters (VSCs) is the preferred option for connection in a multi-terminal dc grid
 - Ratings of up to ± 320 kV and 1000 MW available
 - Multilevel converter technologies
 - No commutation failures
 - AC system strength at each terminal does not affect the performance of the terminal
- Technical challenges
 - Power flow and voltage control strategy
 - Tripping of faulted parts without affecting the rest of the grid
 - Supply of load after isolation of a dc grid segment
 - Protection coordination



Modeling aspects

- Short circuit calculation
- Fault detection and fault clearing
 - Clear faults quickly ($\sim 5\text{ms}$) to avoid instability problems in the underlying ac network
 - High rate of rise of the dc fault current (higher than in ac system)
 - Protection coordination
- DC circuit breakers
 - No zero crossings of the dc current and therefore breaking the dc current is more difficult Fast dc solid-state circuit breakers capable of rapidly interrupting high dc fault currents, however losses are too high ($\sim 30\%$ of converter losses)
 - Hybrid dc breaker topology to minimize losses without compromising the speed of the breaker





Conclusions

- Development of the future network mainly driven by increasing levels of renewable generation (energy mix)
- Network operation:
 - Optimized operation close to real time (flexible system balancing, non-dispatchable generation)
 - Higher level of system integration (EMS, power system simulation tools) and analysis automation
- Network planning
 - Optimization tools to maximize transfer capacity with existing system
 - Investment in new transmission assets
- HVDC grids as a solution for pooling renewable energy
 - Further research and standardization work required



Thanks for your attention

