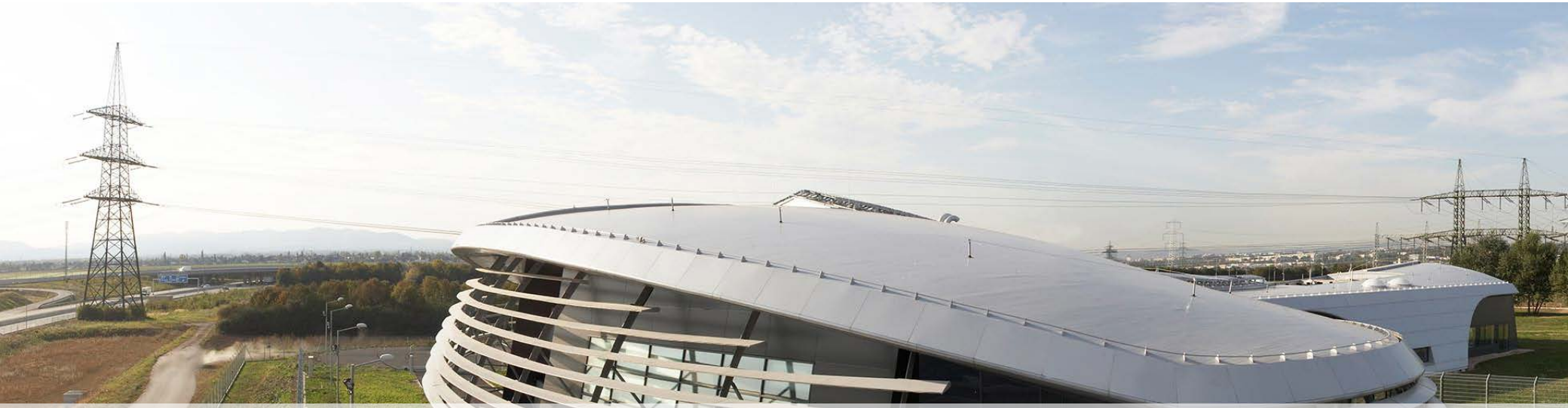


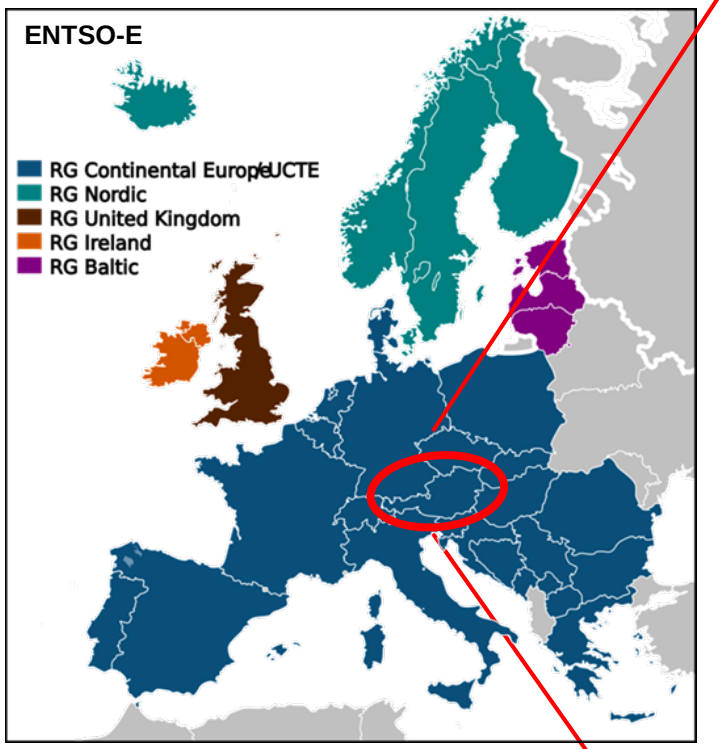
Implementation of a Wide Area Monitoring System (WAMS) for Austria's Power Grid

Dr. Michael Weixelbraun

Austrian Power Grid AG (APG)

International Synchrophasor Symposium, March 22-24, 2016

Austrian Power Grid AG – Key Facts



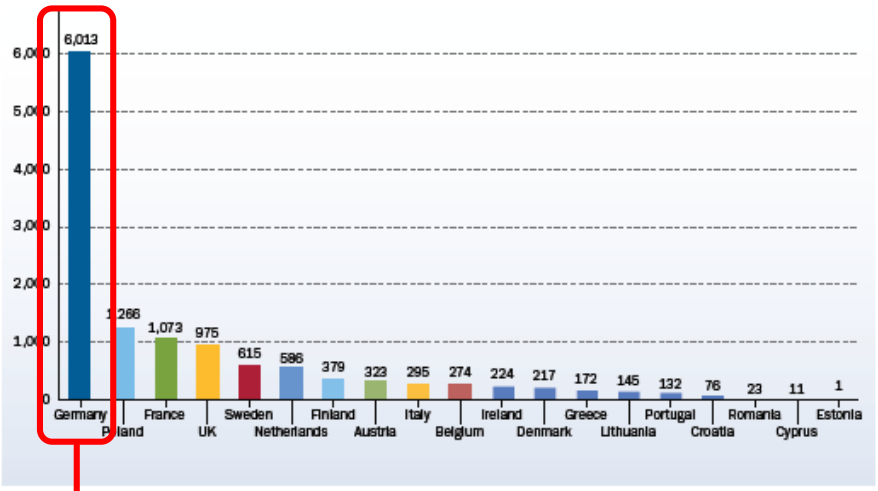
Members
41 TSOs * from 34 Countries
~ 550 Mio. people

- **APG is a regulated enterprise:**
  - Sales revenues*: € 541 million
  - Total Assets*: € 1248 million
  - Yearly Investments: € ~200 million
- **APG is solely responsible for**
  - secure and reliable system operation
  - grid enforcement and development
  - market facilitation and integration
  - forecast and balancing the Renewable Energy Production
- **APG is a full and active member of ENTSO-E**, the European Network of Transmission System Operators for Electricity.

* Figures from 2014 Annual Report.

Energy Change in Europe

EU MEMBER STATE MARKET SHARES FOR NEW WIND ENERGY CAPACITY INSTALLED DURING 2015 (MW). TOTAL 12,800.2 MW



Wind in power 2015 European statistics, 2016

Germany as main driver:

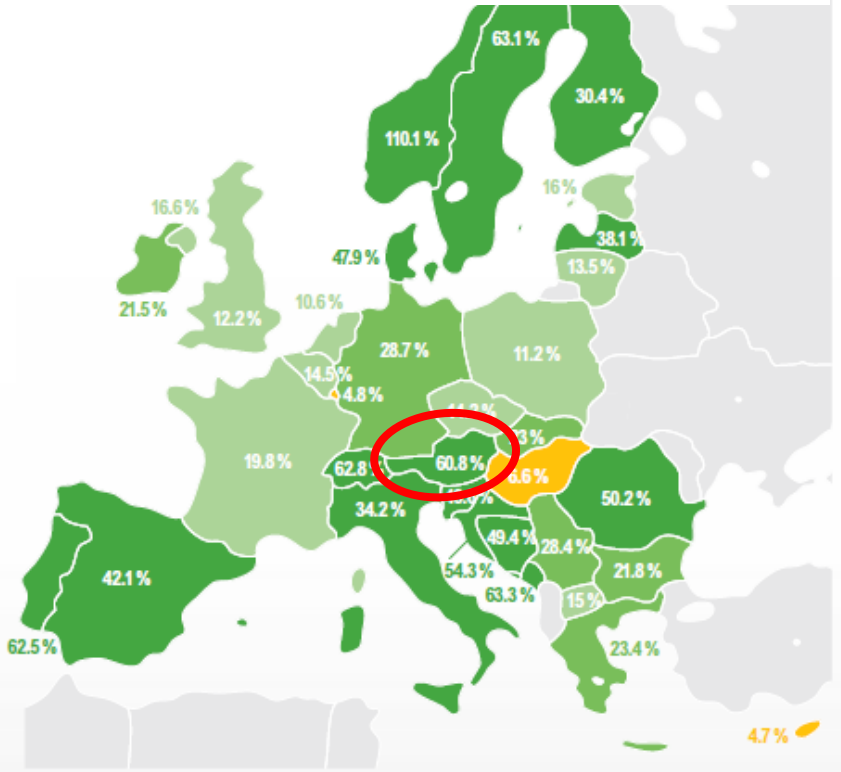
Currently:

- Wind Installed: ~42GW
- PV Installed: ~40GW
- Peak Load: ~ 80GW

Until 2050:

80% share of consumption covered by renewables

Renewable Net Generation in Europe Per Country



SHARE OF CONSUMPTION COVERED BY RENEWABLE GENERATION IN 2014

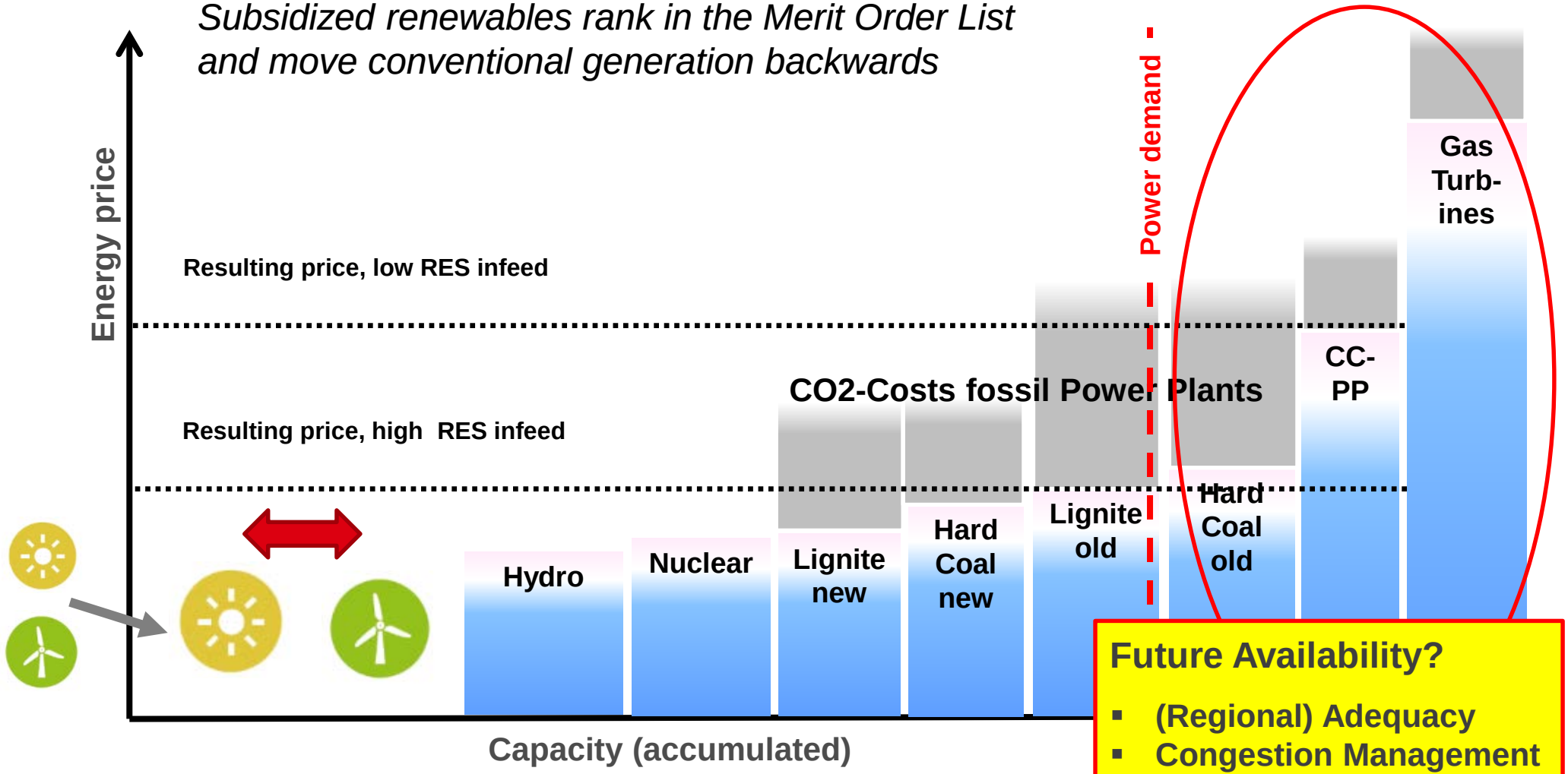
Share of the national generation:

- ≥ 30 %
- ≥ 20 % and < 30 %
- ≥ 10 % and < 20 %
- < 10 %

ENSTSO-E: Electricity in Europe 2014

Supply and demand – merit-order including renewables

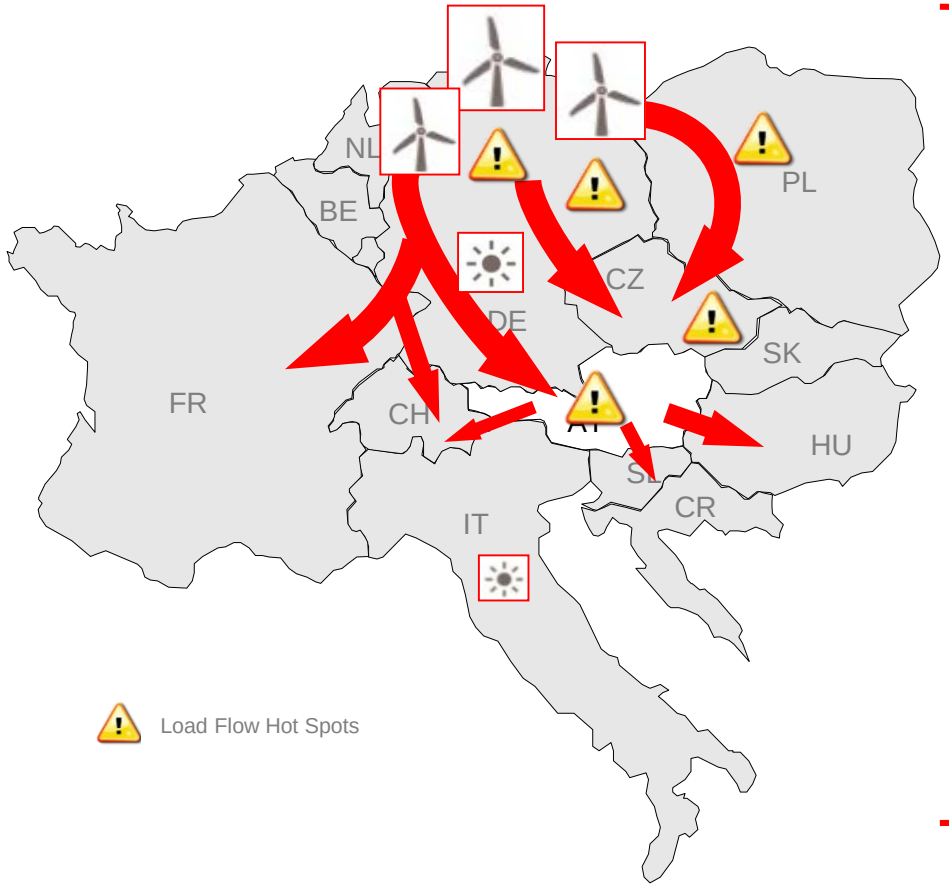
Subsidized renewables rank in the Merit Order List and move conventional generation backwards

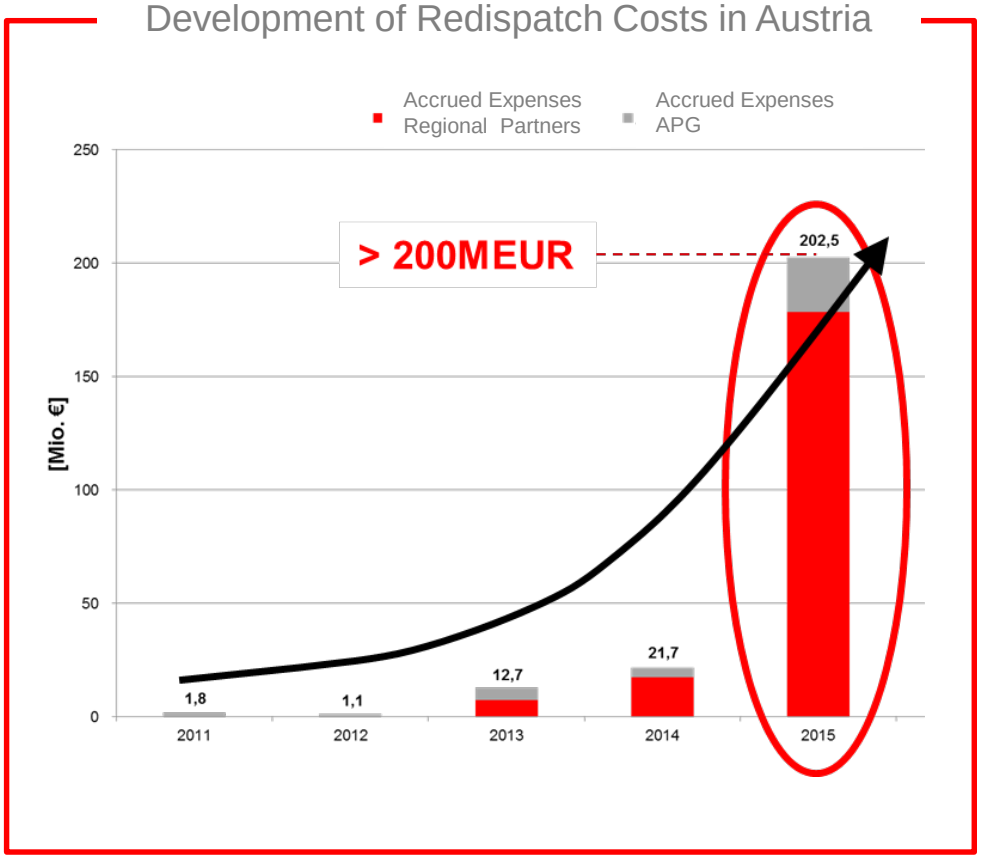


Future Availability?

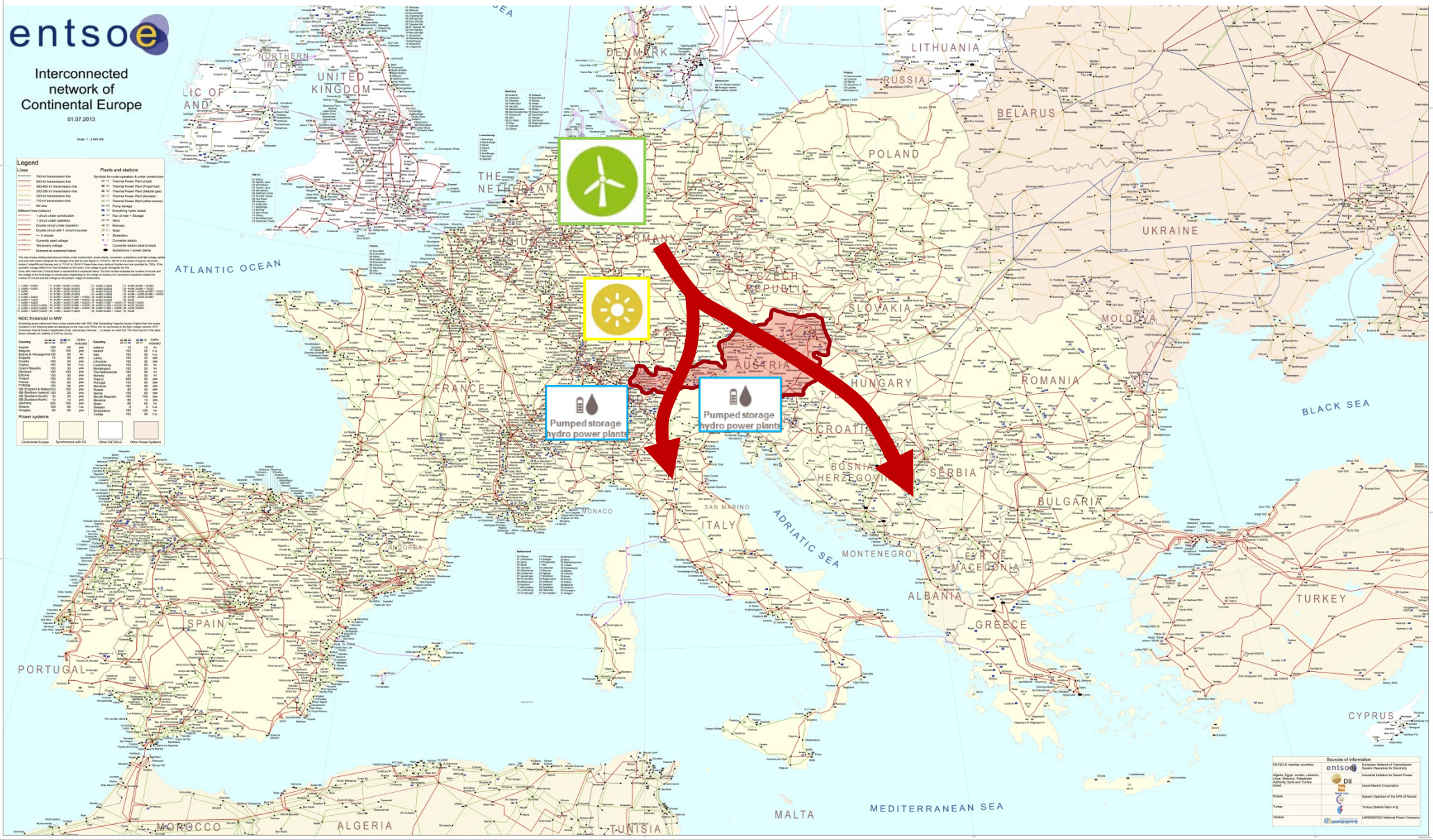
- (Regional) Adequacy
- Congestion Management (Contracted Grid[4] Security Reserves)

Transmission Grid Not Ready Yet To Meet Market Expectations - Congestions Management Costs Increasing

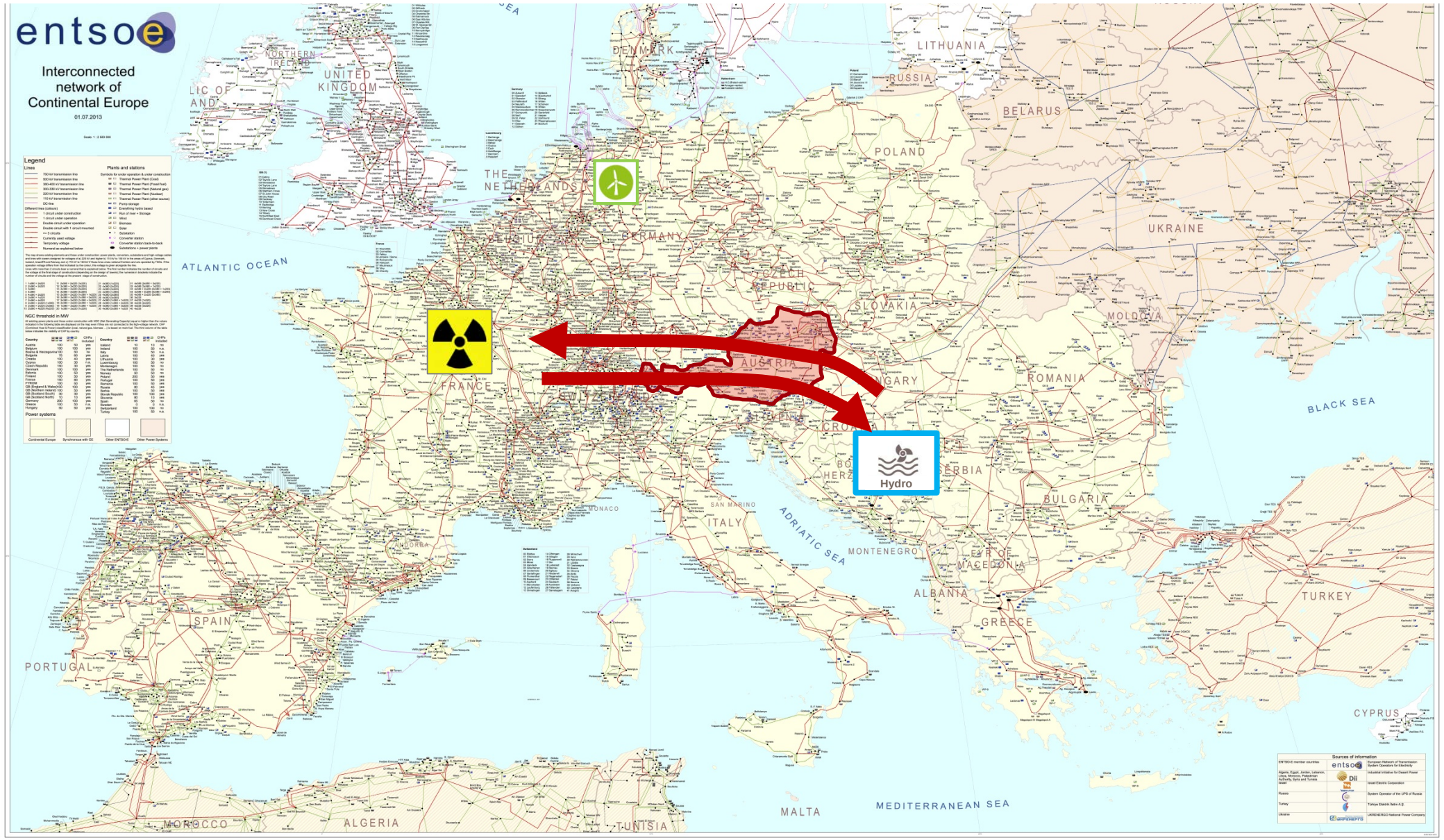




Dominant Load Flow Directions North/South



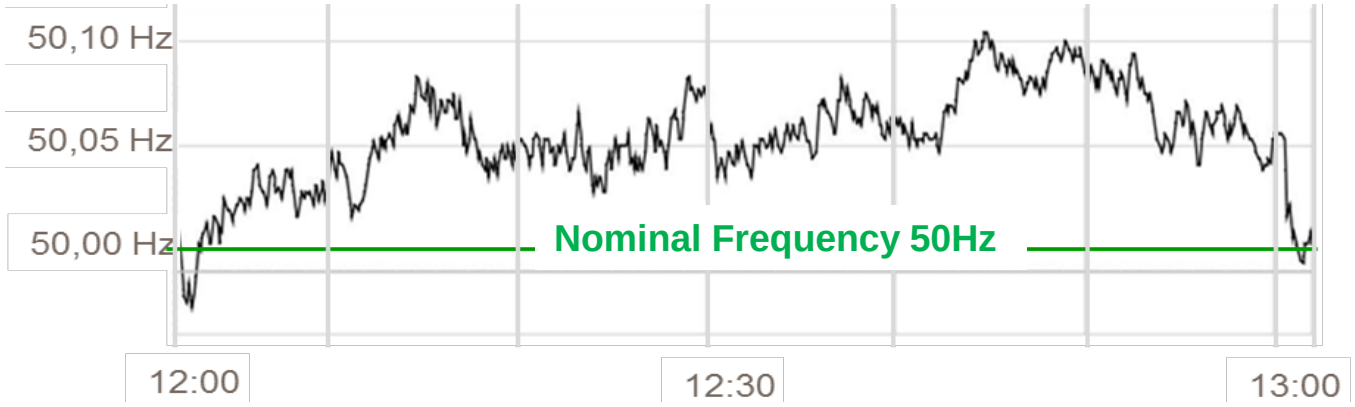
Dominant Load Flow Directions
East/West ↔



Challenging frequency control in Continental Europe

- Imbalances (generation ≠ consumption) lead to **increasing and long lasting frequency deviations**
- **Major reason:** Volatile RES infeed from PV/Wind power plants and obviously overloaded balancing reserves in several control zones

Example of frequency deviation lasting for more than 1h with peaks above 100mHz



Development of Binding European Standards – Network Codes and Guidelines

System Operation Related Codes

- Operational Security (OS)
- Operational Planning & Scheduling (OPS)
- Load Frequency Control & Reserves (LFCR)
- Emergency and Restoration (ER)

Grid Connection Related Codes

- Requirements for Generators (RfG)
- Demand Connection Code (DCC)
- HVDC Connection Code (HVDC)

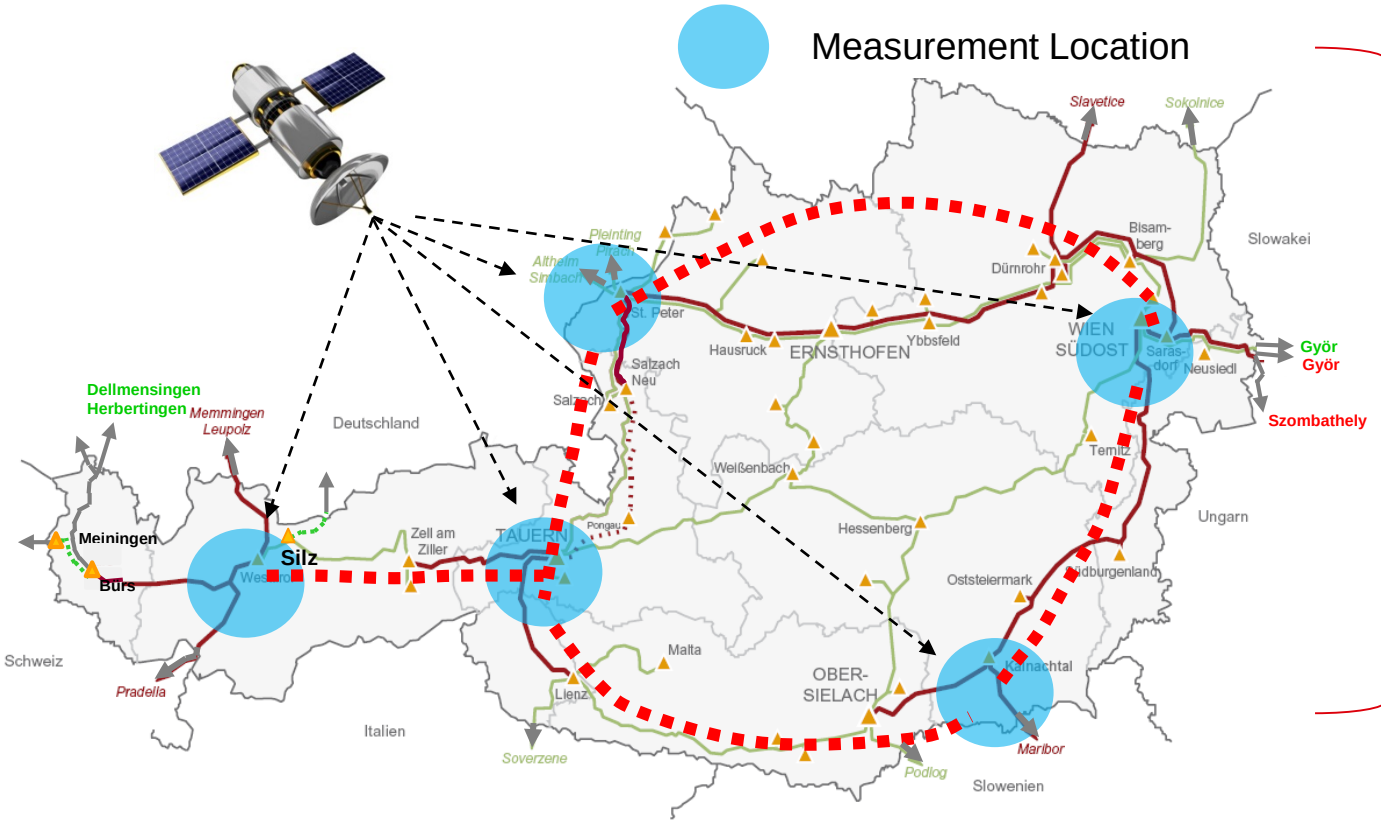
Market Related Guidelines

- Capacity Allocation & Congestion Management (CACM)
- Forward Capacity Allocation (FCA)
- Balancing Network Code (EB)

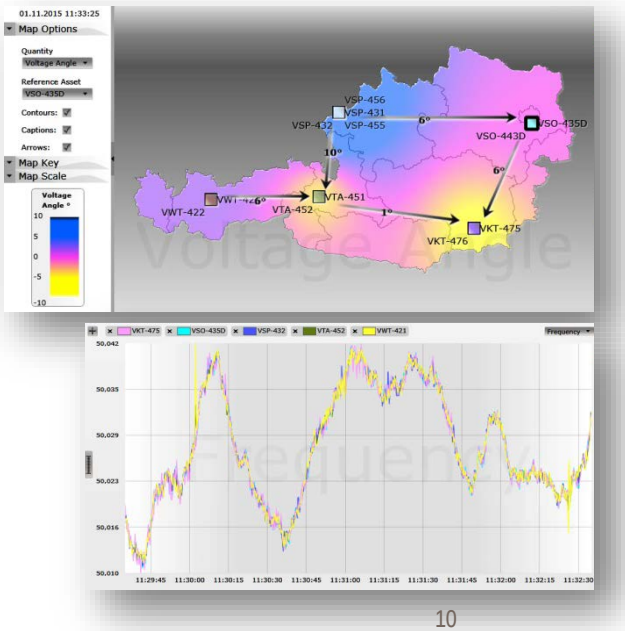
Transmission System Operators responsible for development, implementation and monitoring of Codes

For more details: Follow http://networkcodes.entsoe.eu/

New Wide Area Monitoring System at APG



- Went Live: 02/2016
- 5 measurement locations, 12 PMUs
- Redundant server system

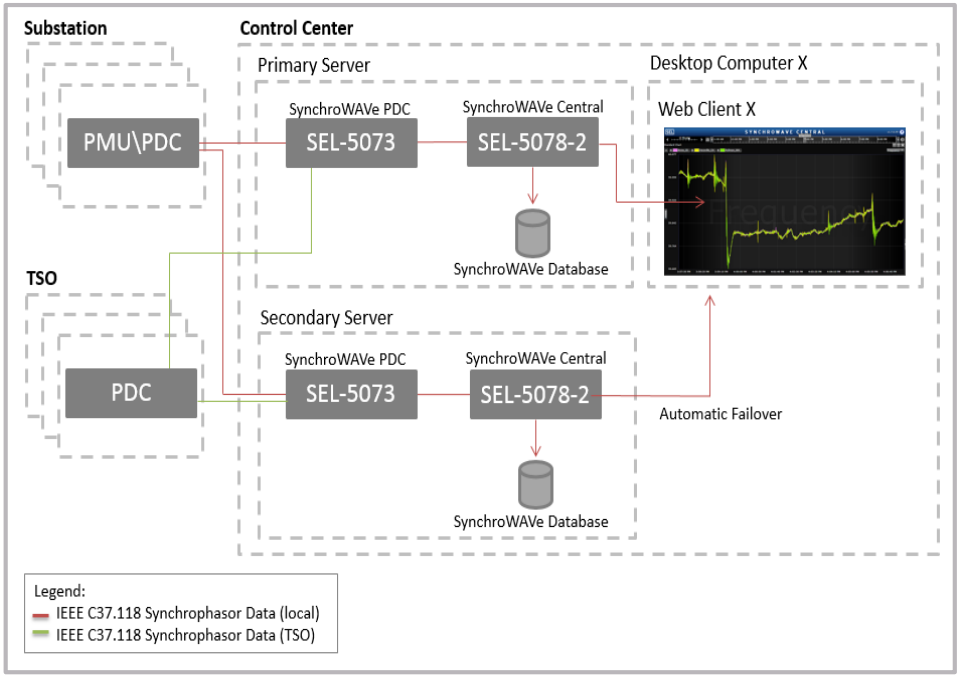


Further developments:

- **Enhanced data exchange in Continental Europe**
- **Development of “dynamic remedial actions”**

APG WAMS – Architecture

- PMUs in dedicated closed network (SZW)
- PDCs run hot/hot with SynchroWAVe Central Software
- 2 Redundant Servers on different locations, with dedicated data streams
- Servers are locked in DMZ (DeMilitarized Zone), special authorization needed to access visual presentation
- IT-Security - Challenging Implementation

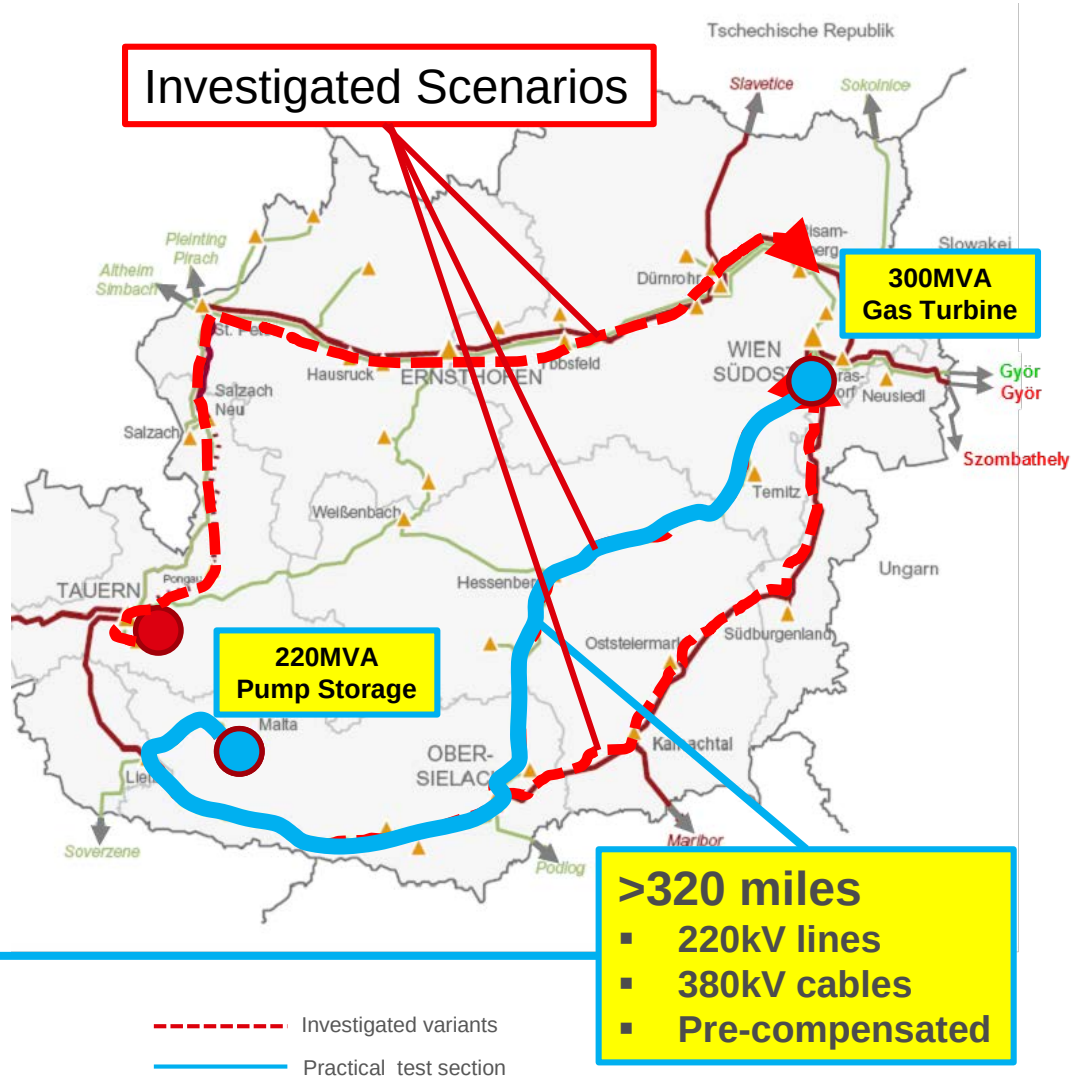


Measurement Example: Enhancement of APG's Restoration Concept – Voltage Ramping

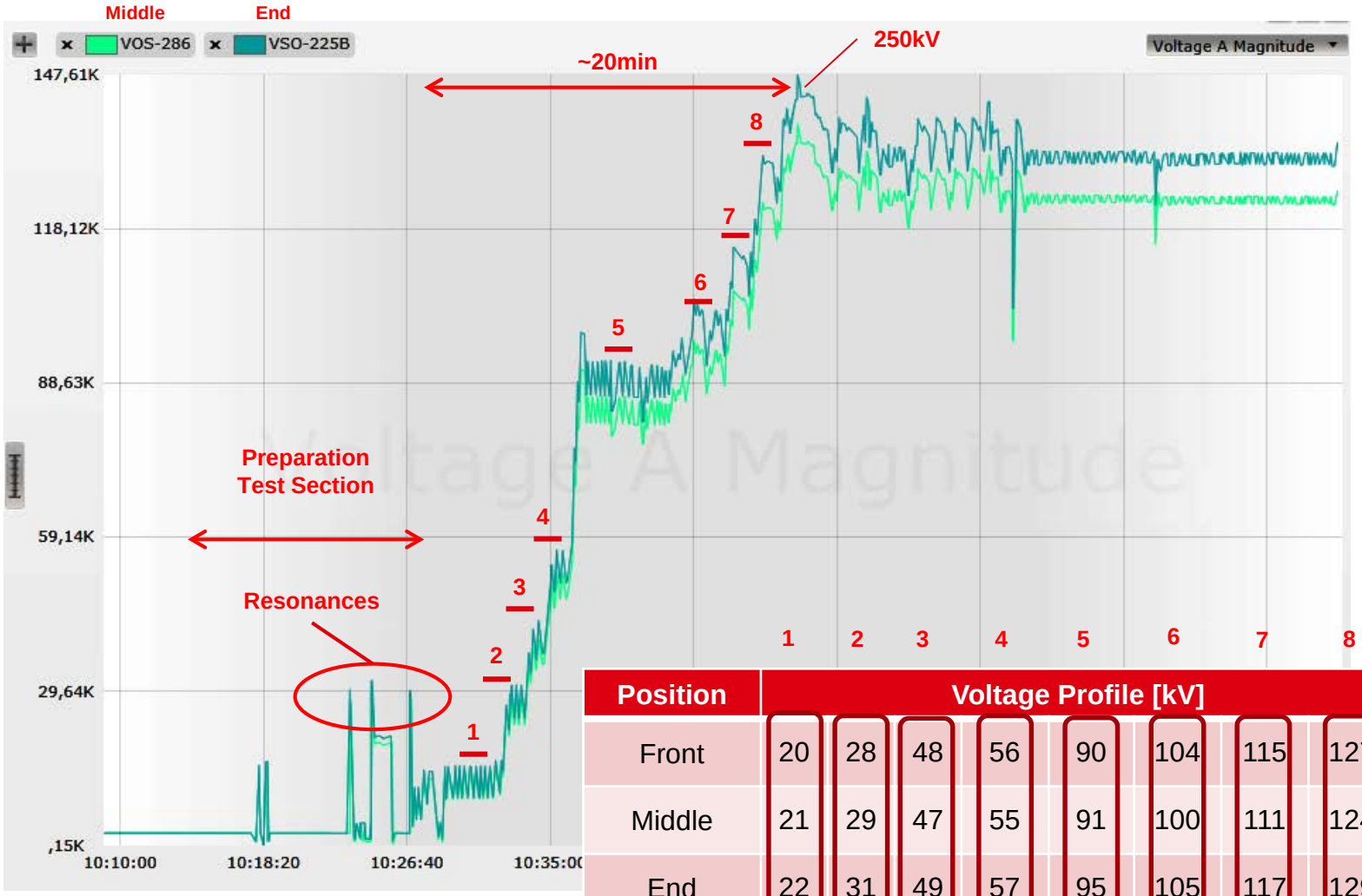
- Method: Ramping of a pre-compensated power line section at no load
- Transformers towards 110kV level are also connected (inrush prevention)
- Flexible option for system operator in case of restoration
- Benefit
  - Redundant, time efficient restoration option for eastern Austria
  - Restoration of auxiliary supply of substations in eastern Austria

✓ Simulation study (Graz University of Technology)

✓ Practical test 13.03.2016

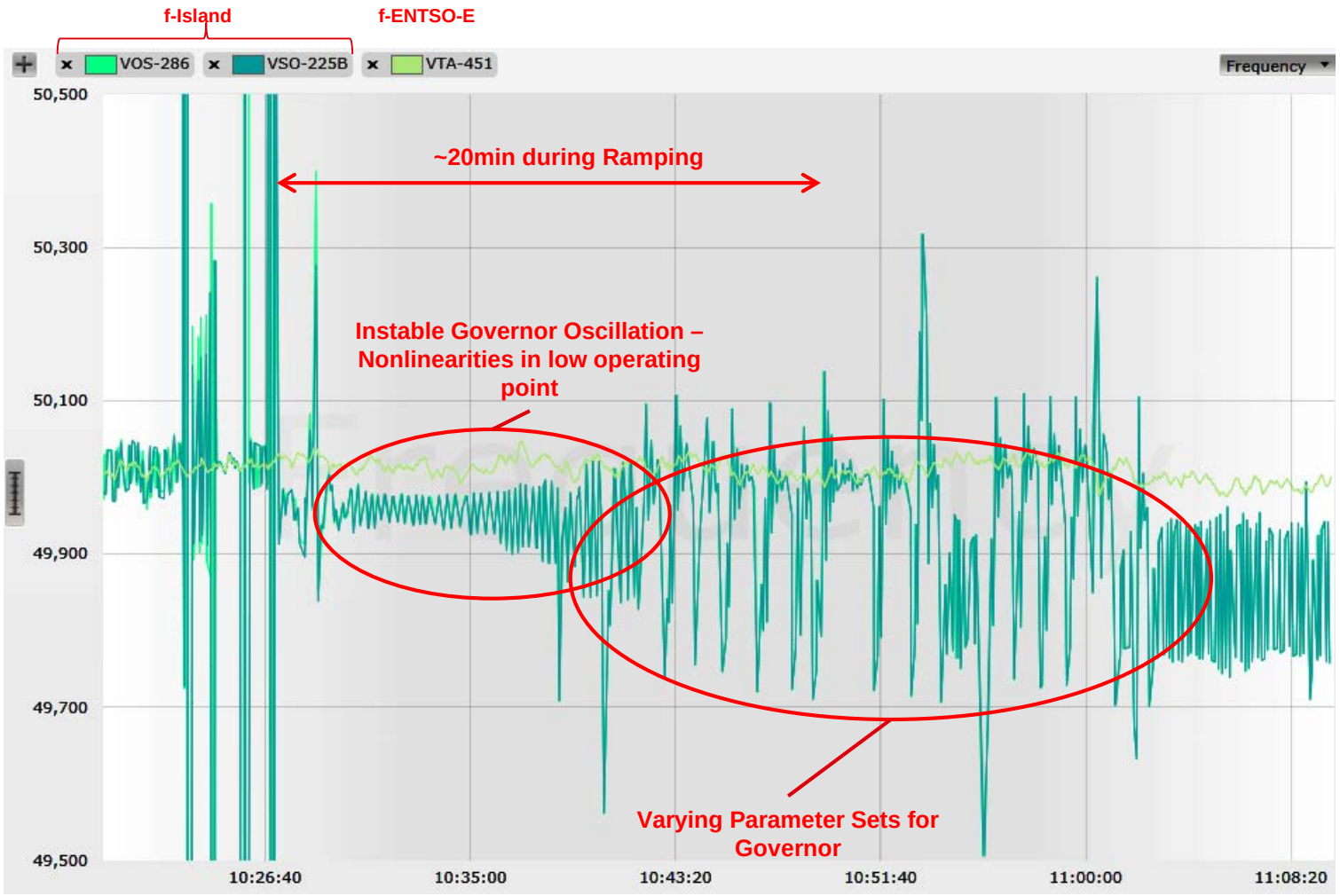


Energizing Power Lines, Transformers - Voltage Ramping

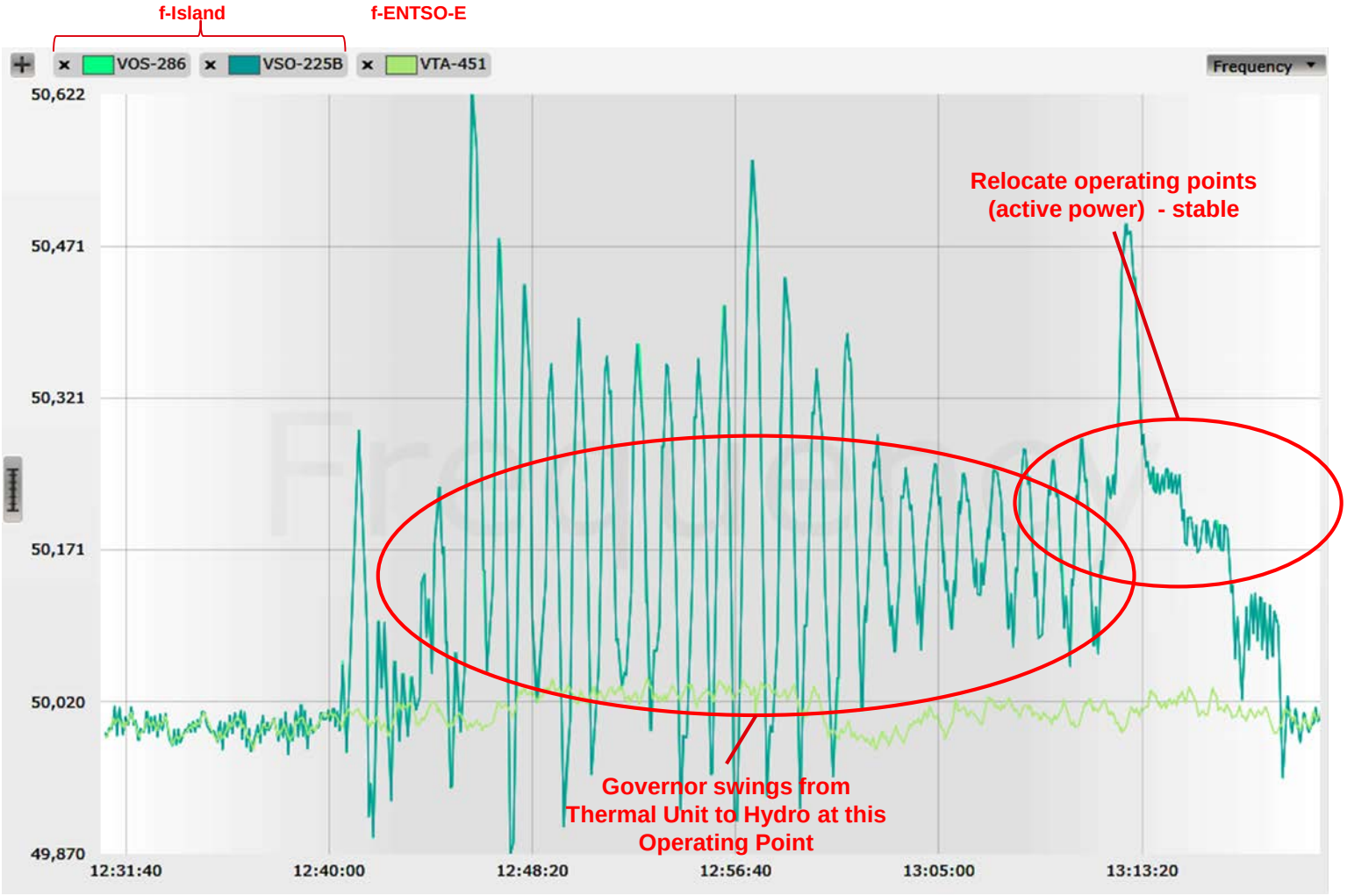


Position	Voltage Profile [kV]							
	1	2	3	4	5	6	7	8
Front	20	28	48	56	90	104	115	127
Middle	21	29	47	55	91	100	111	124
End	22	31	49	57	95	105	117	129

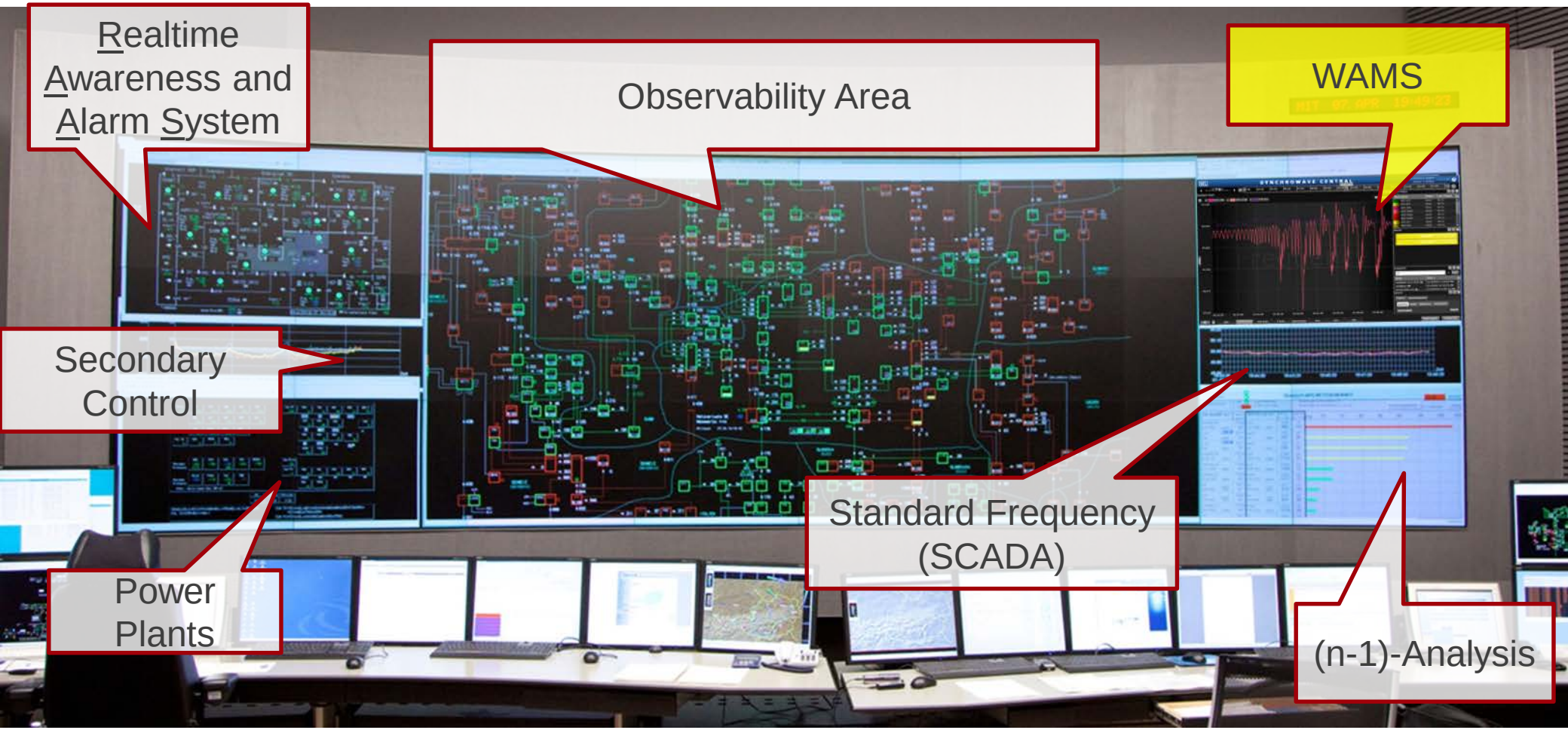
Hydro Governor Characteristics at No Load - Parameterization



Connecting the Power Plants – Finding Proper Operating Points



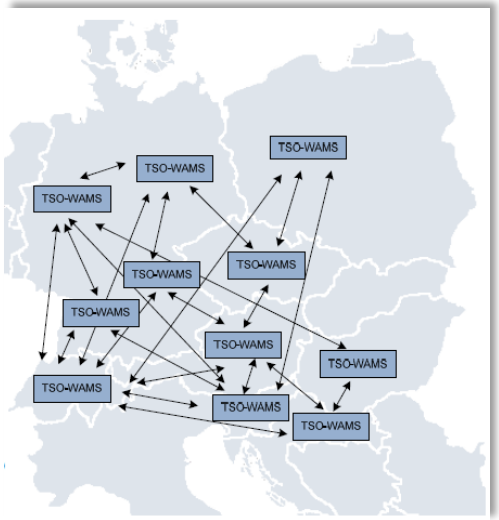
System Operator’s View

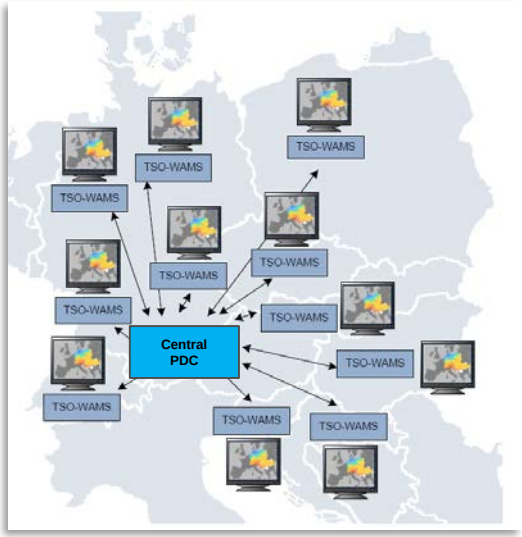


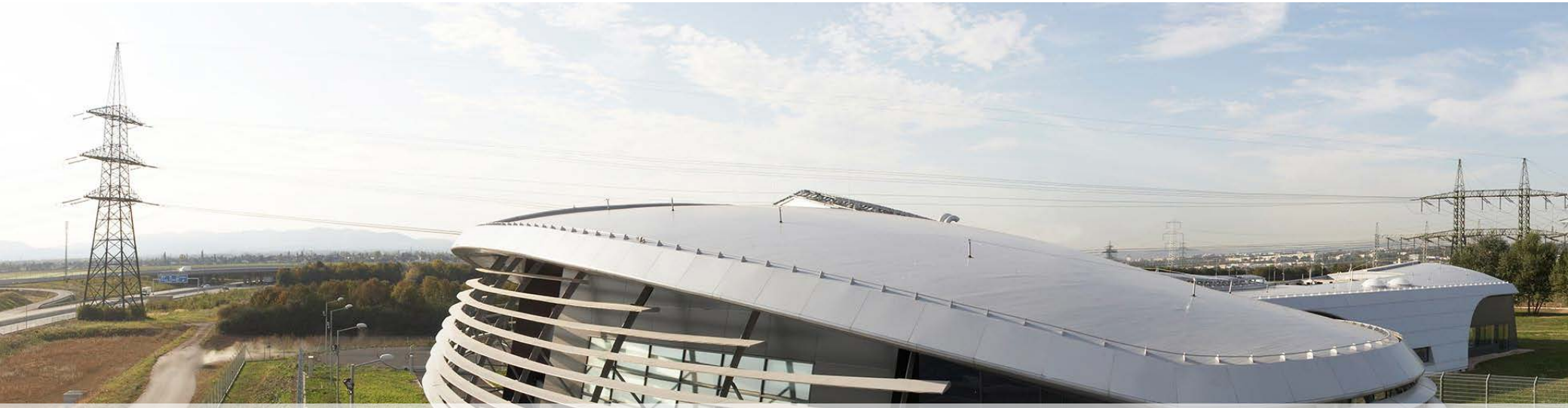
* SRL = Sekundär-Regel-Leistung

Future Developments and Challenges

- Data exchange between TSOs is legally formalized by bilateral agreements at the moment
- Exchange and utilize data more efficiently (technically, administrative)
- Develop a high-level concept for real time monitoring and an awareness system based on WAMS technology
- WAMS is core system to capture dynamic characteristic of the system in changing environment







Implementation of a Wide Area Monitoring System (WAMS) for Austria's Power Grid

Dr. Michael Weixelbraun

Austrian Power Grid AG (APG)

International Synchrophasor Symposium, March 22-24, 2016