Current Issues in Power System Research

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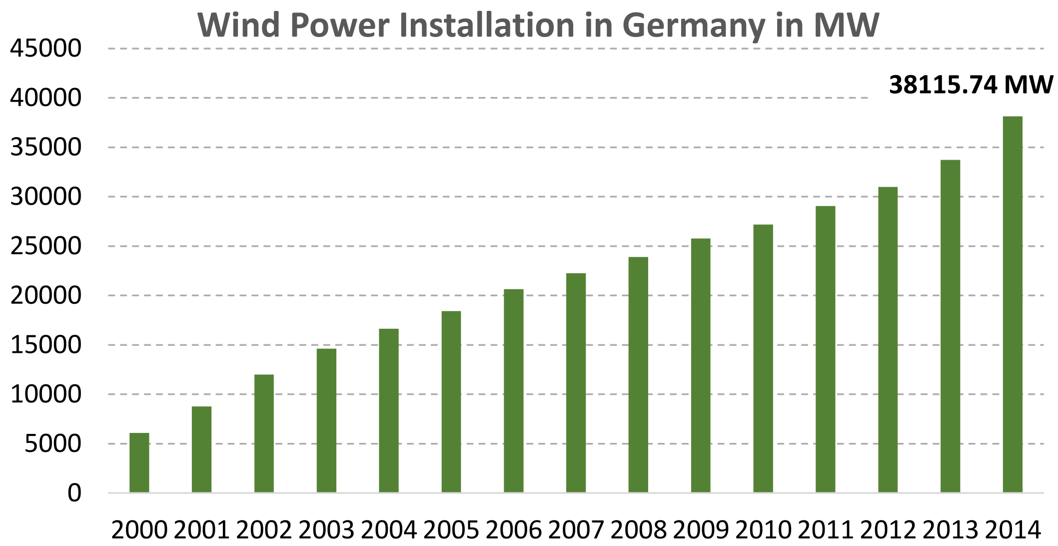
Outline

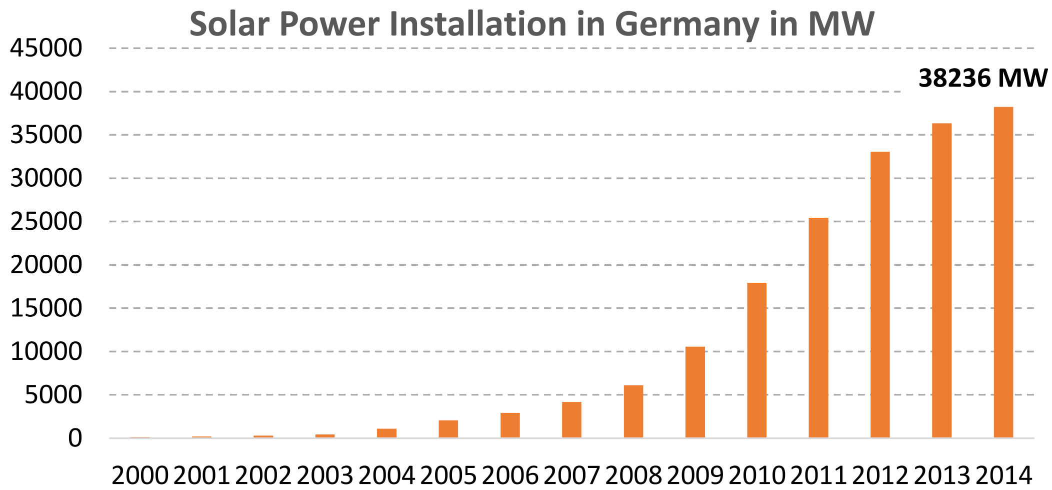
- Challenges in future power systems
- Selected nonconventional approaches

Current Situation

- Transition from conventional fossil fired and nuclear power plants to renewable power generation
- Distribution grid becomes “active” by renewable generation
- Considerable power transmission from the north to the south
- Power trading resulting in load flow restrictions
- Grid utilization increases; some lines reach maximum capacity
- Grid extension is limited and implementation is behind the schedule
- Large scale application of converter based generation units and transmission systems
- Increasing portion of underground cable
- Economical pressure and political interventions

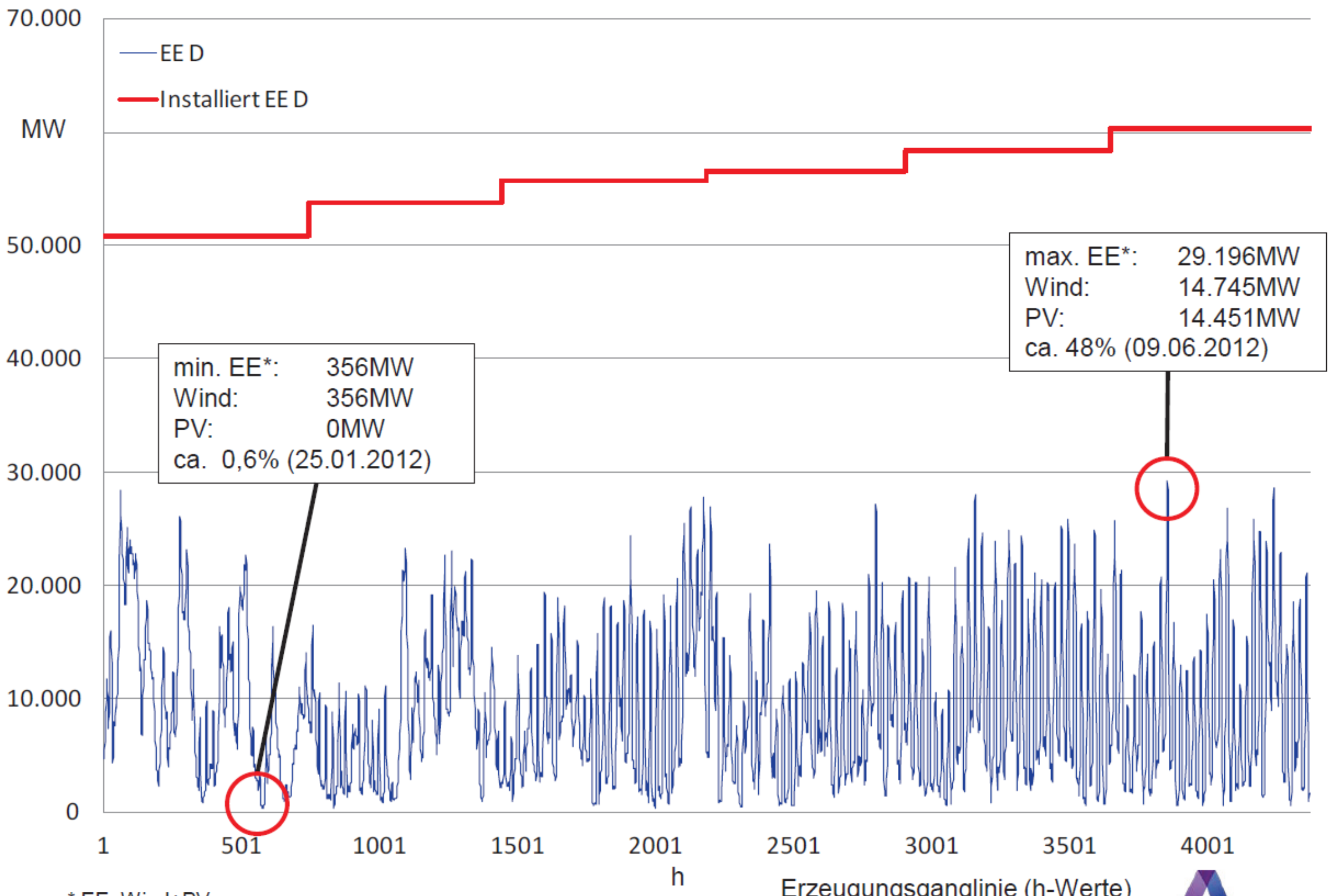
Development of Wind and PV Power in Germany





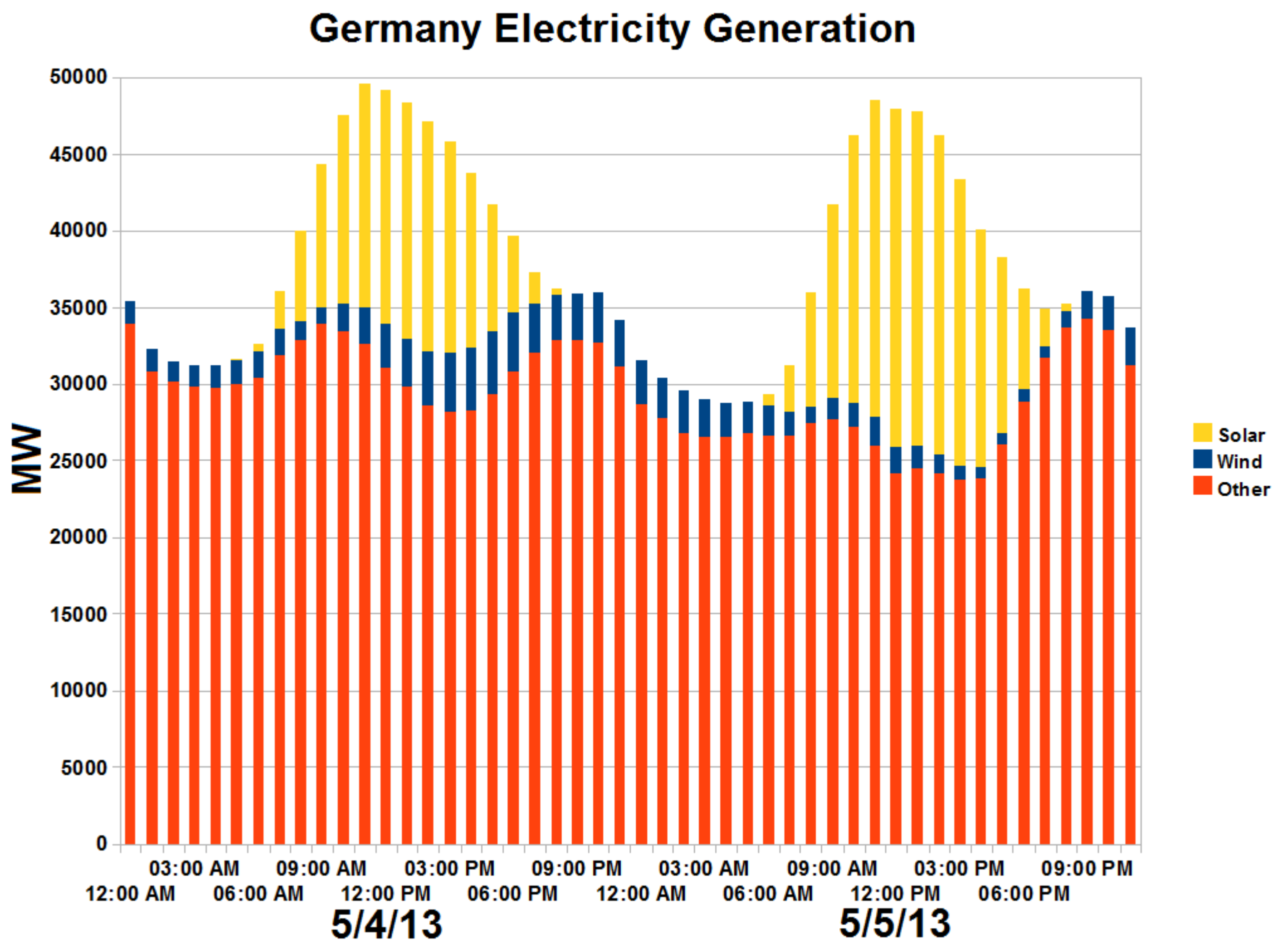
Source: Statista 2015

Volatility of RES

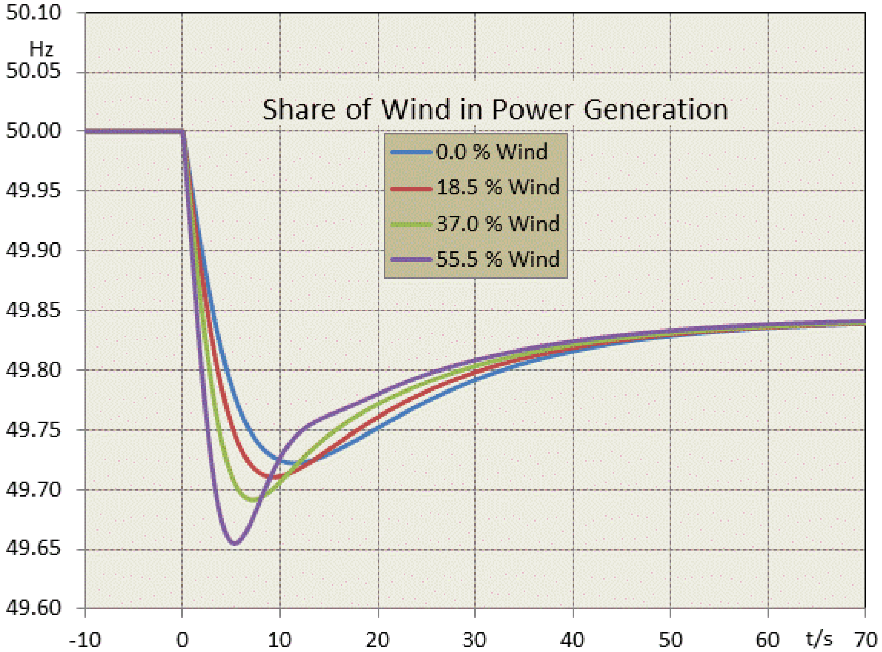


* EE: Wind+PV

Distribution of Solar Power Generation



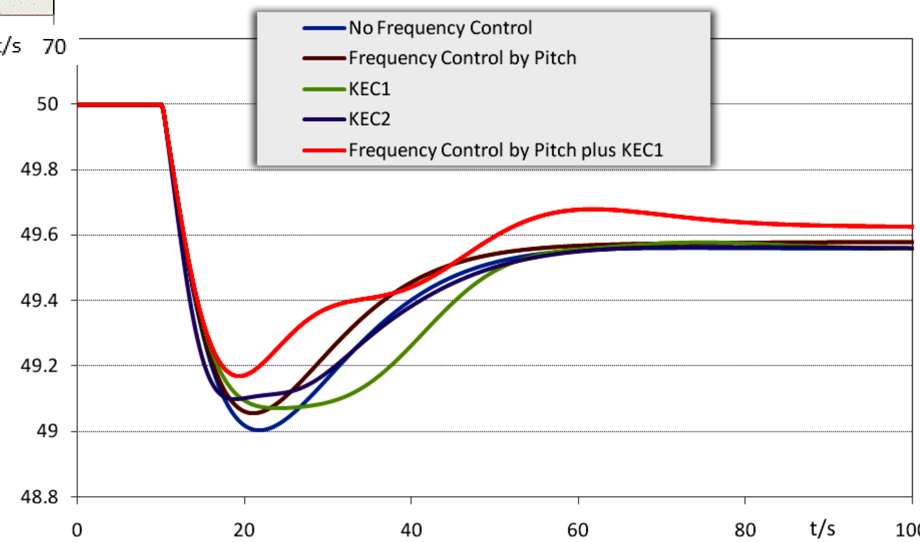
Reduced Inertia in the Grid



Due to power electronic supply:

- Rate of frequency change will increase
- Frequency minimum is deeper and reached faster

Different control options

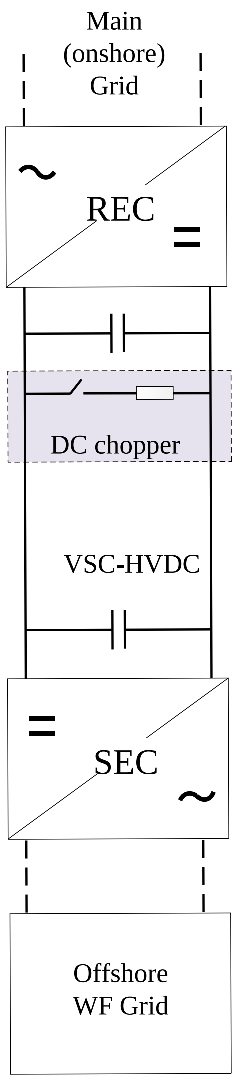


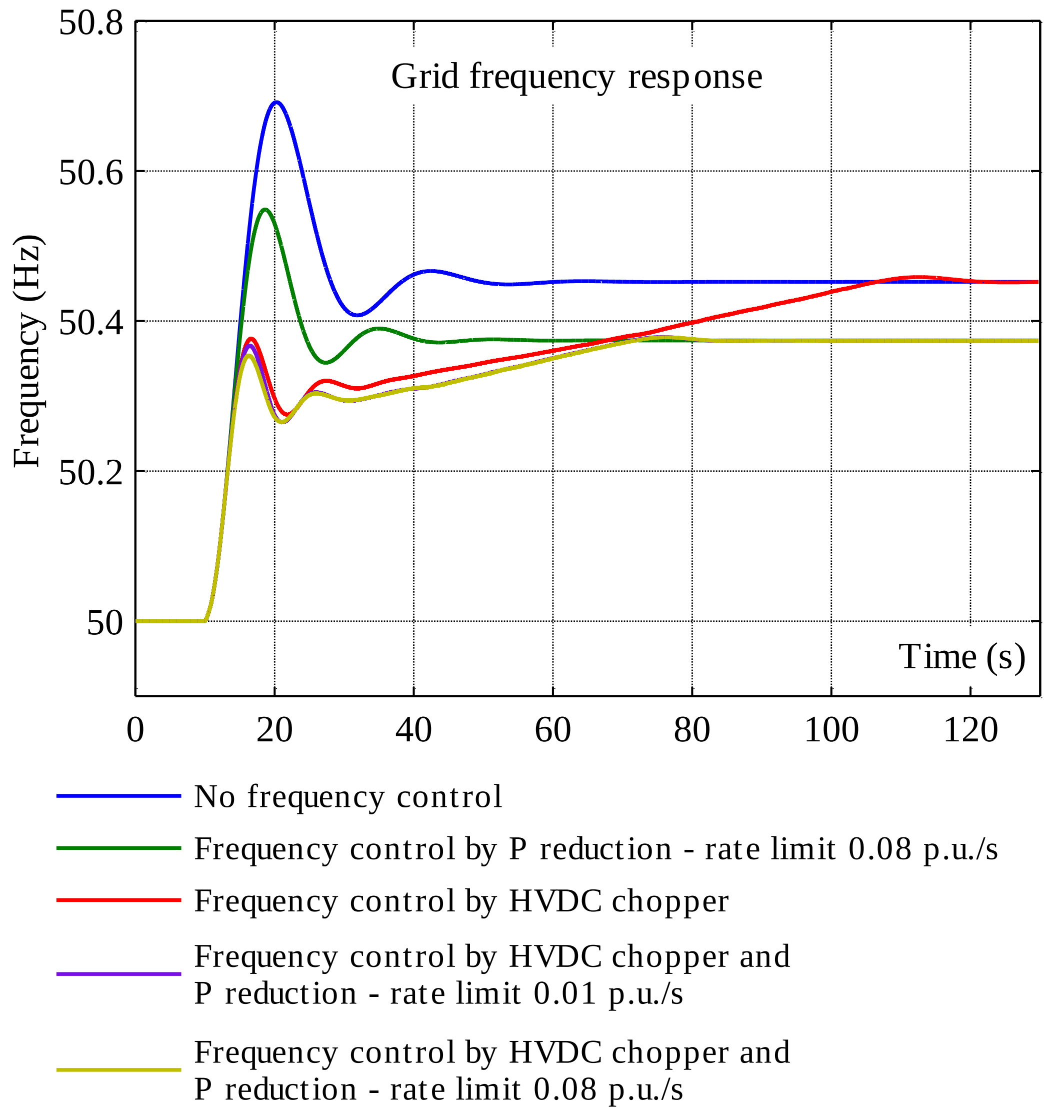
Inertia control can help only temporary

- The effect is limited to 10-20 seconds
- The subsequent recovery phase is even more challenging

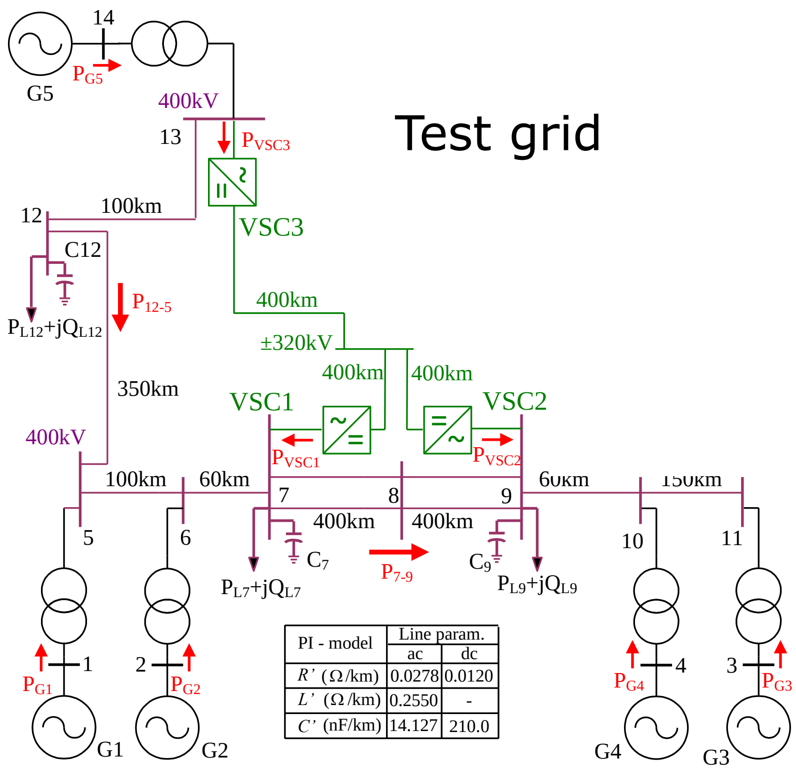
Utilizing of DC Link Chopper for Overfrequency Limitation

Triggering the DC link chopper by overfrequency





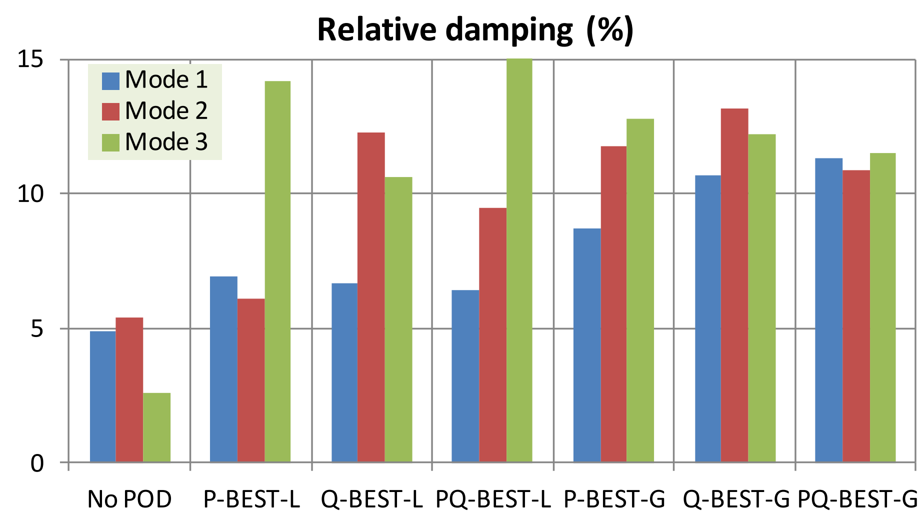
Damping Control by VSC-HVDC



PI - model	Line param. ac	Line param. dc
R' (Ω/km)	0.0278	0.0120
L' (Ω/km)	0.2550	-
C' (nF/km)	14.127	210.0

Test grid

VSC-HVDC represents not only a active power transmission but also Var sources on both ends
Two independent control channels are available on both ends



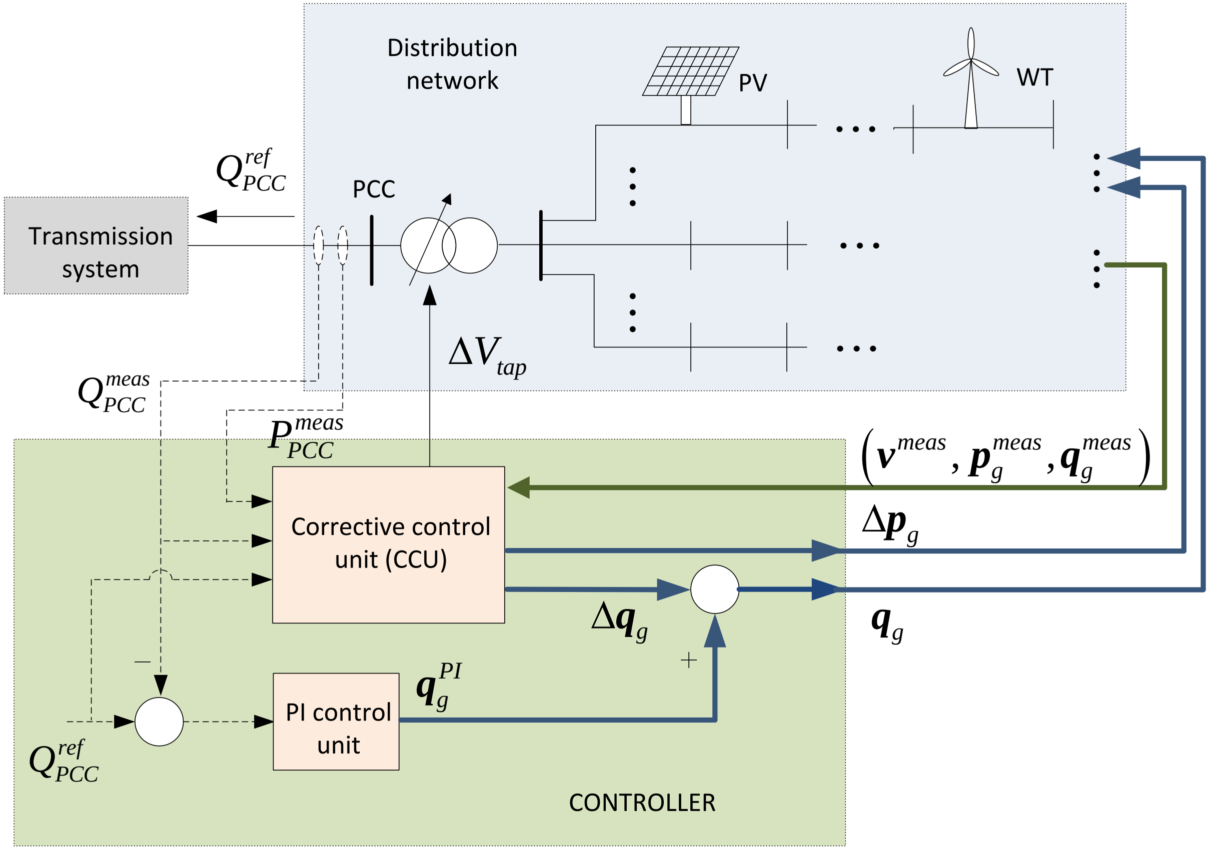
Different damping control options

VSC-HVDC can be use to damp electromechanical oscillations by **utilizing both active and reactive power control channels.**

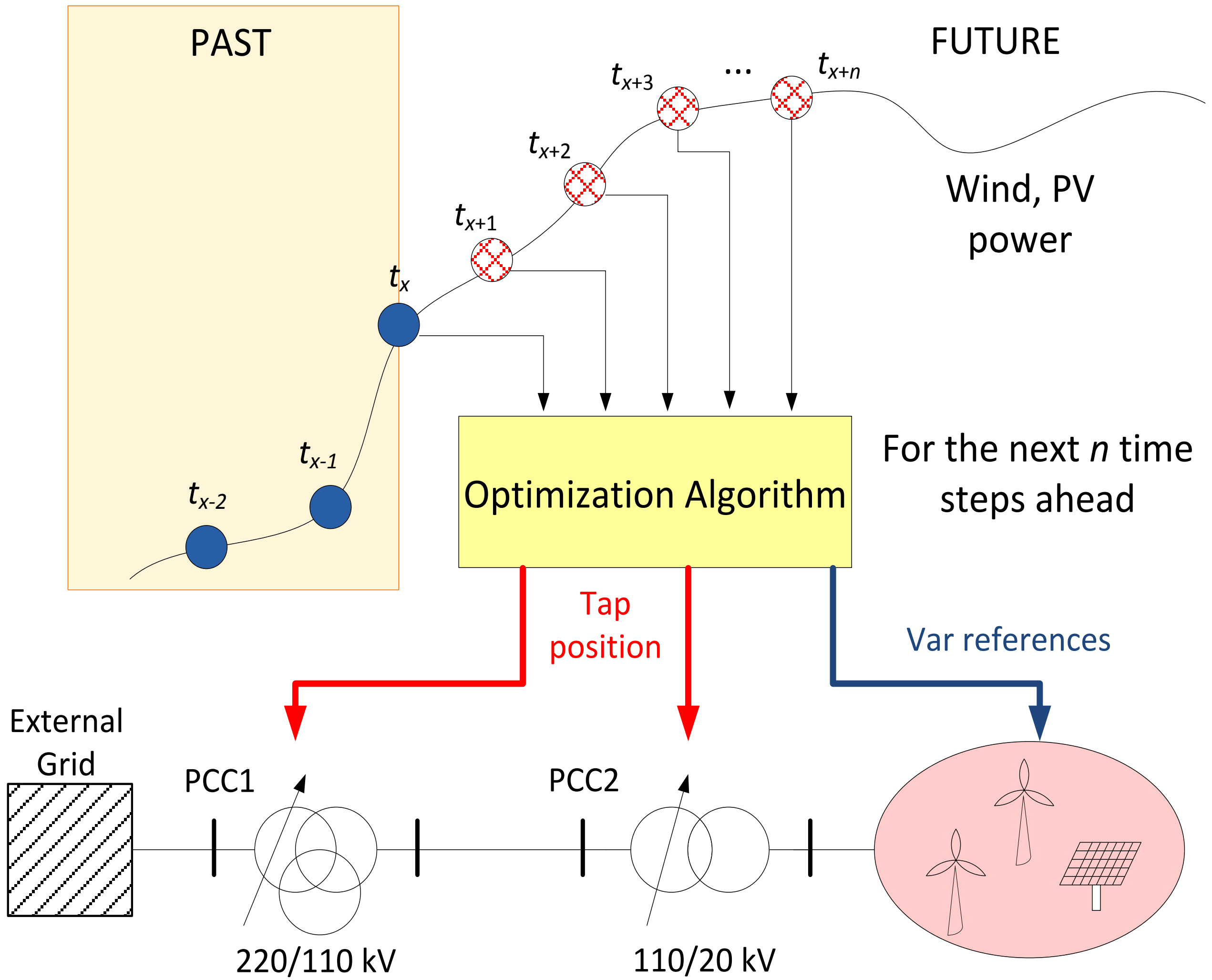
Distribution Grid Voltage-Var Control

Objective: supply of Q_{ref} in PCC by optimally utilization of Var sources

Restrictions: Limited grid measurements are available



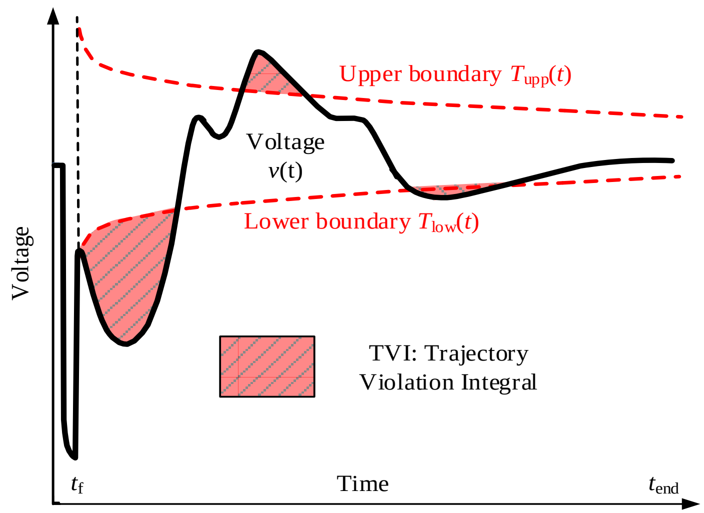
Predictive Optimization and Control

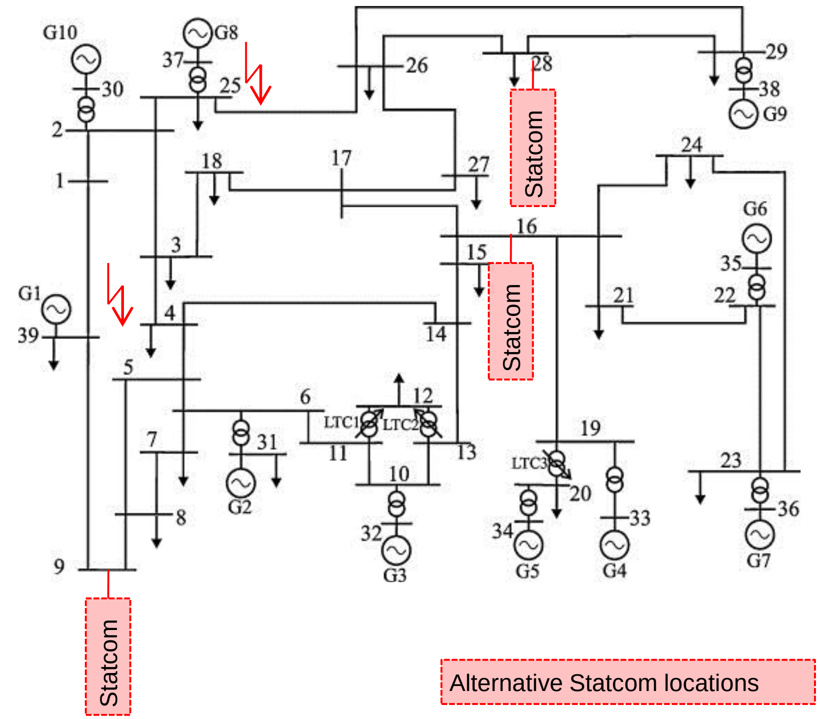


Short term wind forecast is required max. 15 min. ahead

Optimal Allocation and Sizing of Statcom

Quality measure: TVI=0
Voltage behavior within boundaries





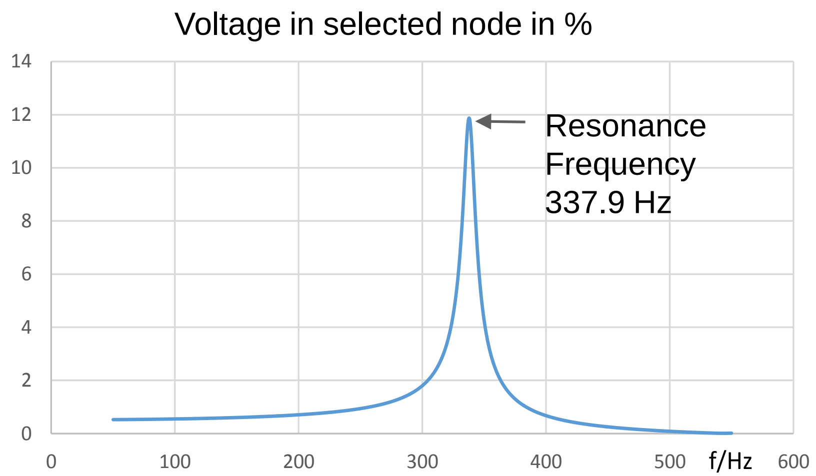
Objective: Minimize investment and operational costs

s.t. : System response to preselected faults and Var locations

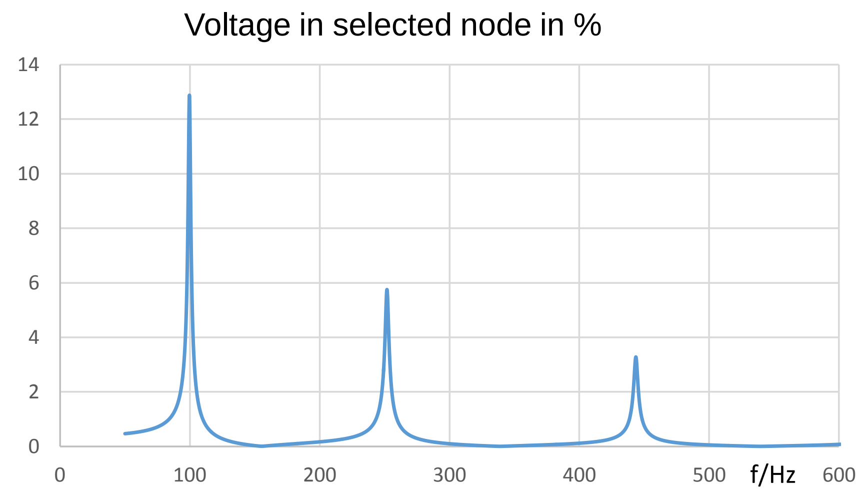
Stochastic optimization by taking into account the probability of different scenarios.

Harmonic Stability

Frequency Characteristic of 200 km, 400 kV Overhead Line



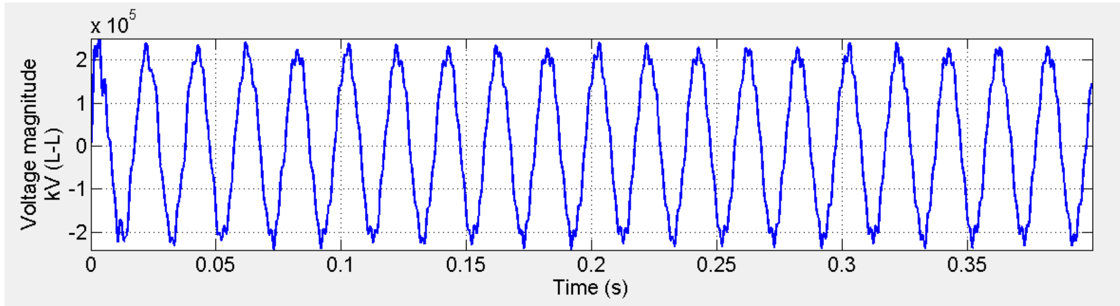
Frequency Characteristic of 200 km, 400 kV Underground cable compensated every 50 km

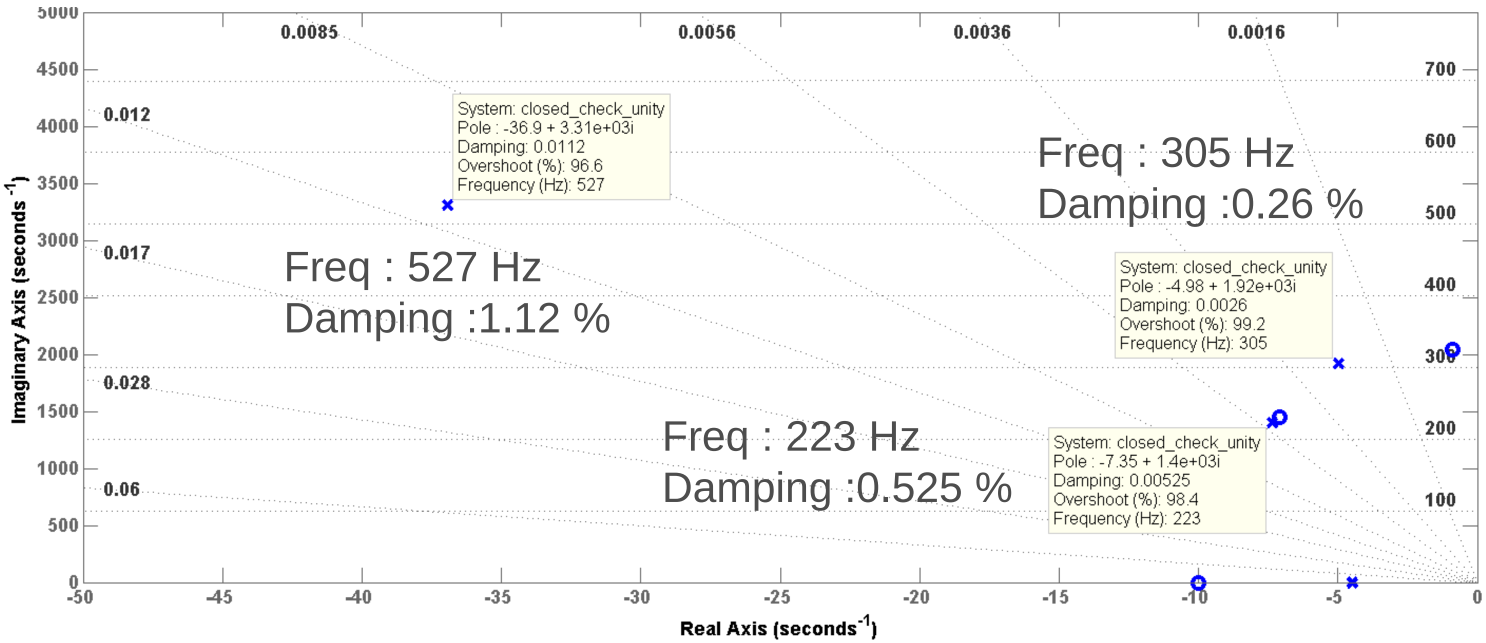


The resonance is excited by injecting 1% voltage source of corresponding frequency

➔ The number of resonance in a grid dominated by underground cables will increase.
The same time, due to the large number power electronic equipment, the number of sources may excite the resonance will also increase.

Example for Harmonic Stability Study

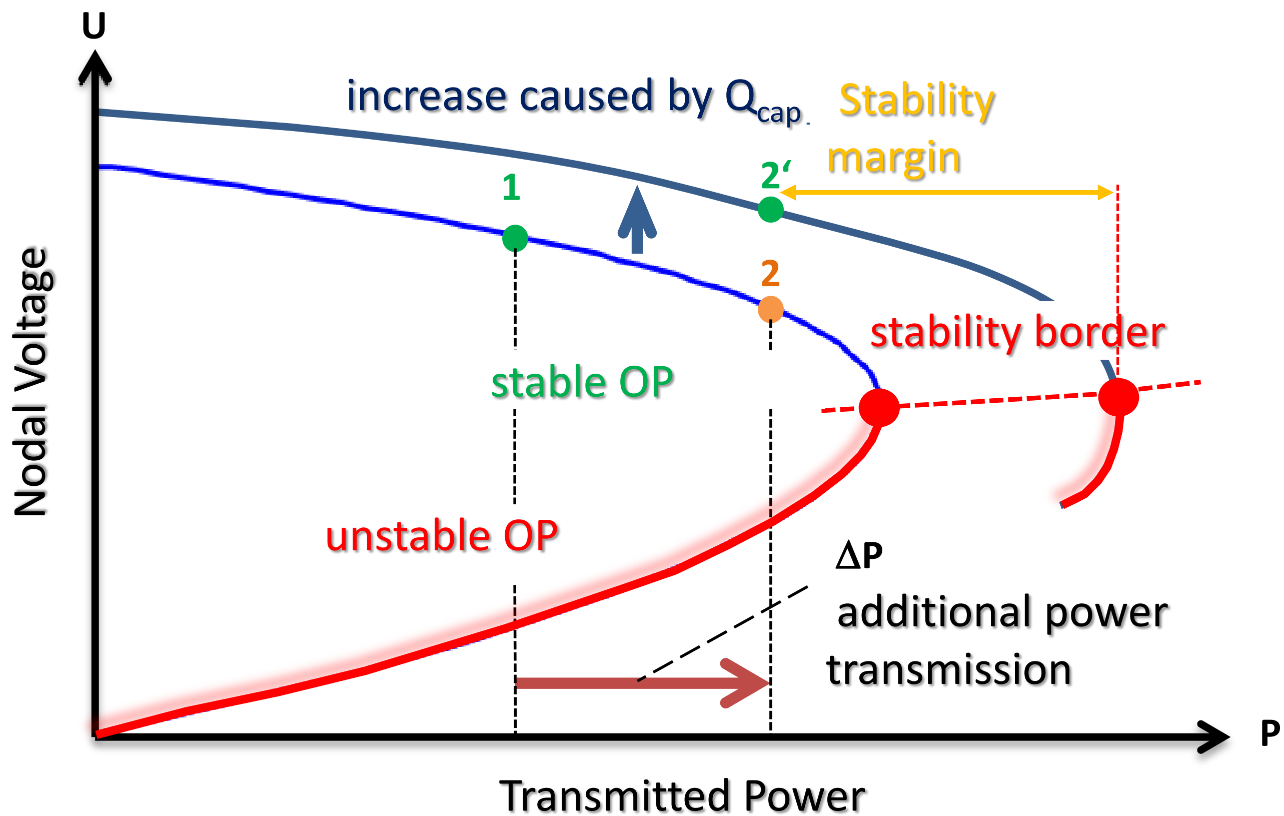




Improved methods for analyzing and controlling harmonic stability problems are required (modal analysis including numerical linearization, disturbance rejection control, damping control)

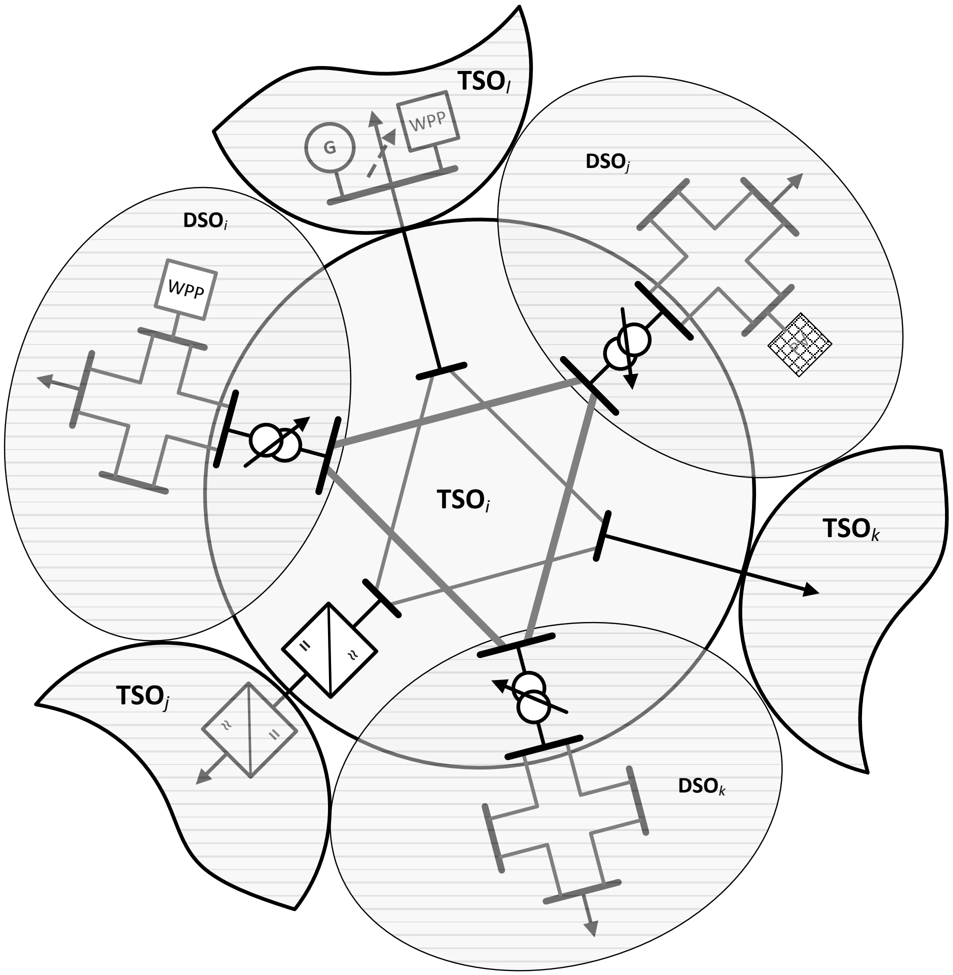
Voltage Stability

Effect of increased power Transmission



Online voltage stability assessment methods are required applicable in a large strongly mashed transmission grid

Dynamic Security Assessment



- Large number of Wind and PV generation units
- Large number of small Voltage

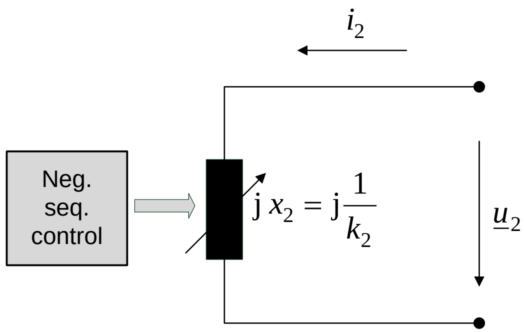
  Source Converter (VSC)
- Embedded VSC-HVDC

➔ Active distribution grids, dynamic characteristic of “Loads” will change

- Limited information exchange between TSOs
- Character of dynamic phenomena will change due to power electronic components and underground cables

➔New DSA approaches are needed ➔ preventive/corrective control

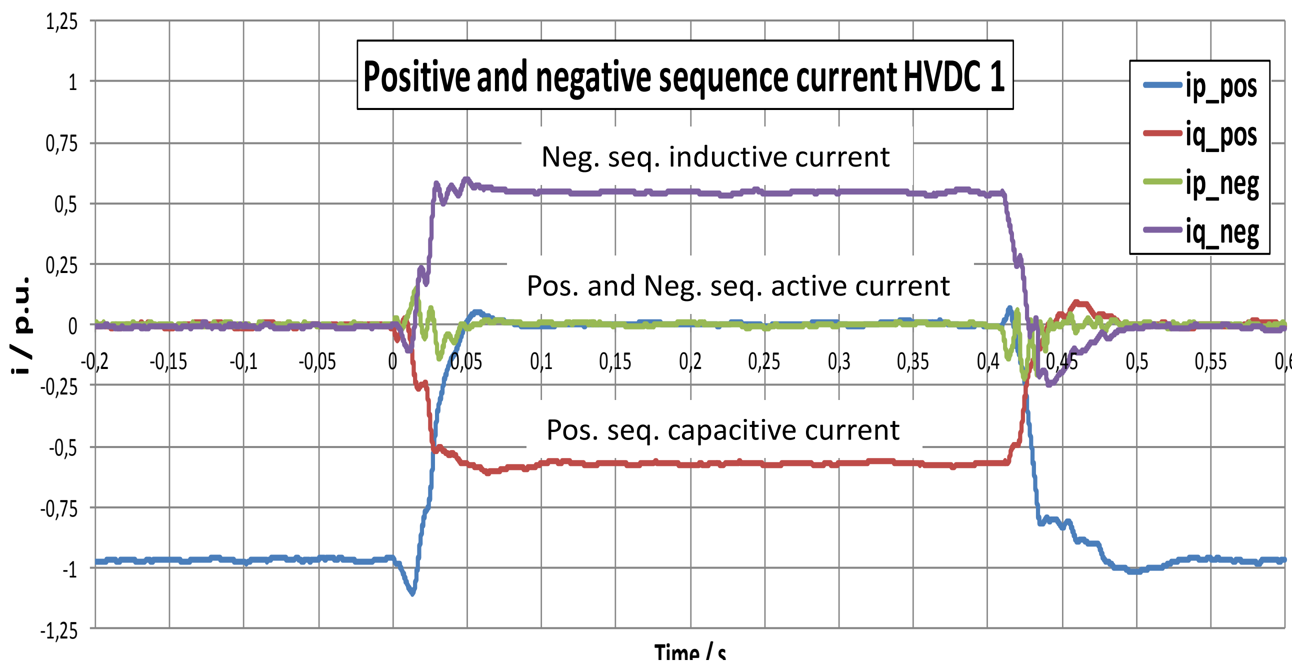
Separate Positive and Negative Sequence Control by Voltage Source Converter



Control for injecting neg. seq. current through a virtual reactance

$$\mathrm{j}\,x_2 = \mathrm{j}\frac{1}{k_2}$$

Alternative Approaches ?



How to deal with Uncertainties?

Uncertainties due to:

- Volatility of renewable energy supply
- Forecast error
- Electricity trading
- Grid extension delays
- Political decisions
- New technical phenomena
- Acceptance by the society

➔ increased utilization of stochastic methods in power system planning, operation, assessment and optimization

What we need

- Hierarchical schema of local and global control and protection agents which allow optimal operation, are adaptive and robust
- Systematic development of the communication network for power system applications which provides redundancy and is immune against cyber attacks
- Development of new control approaches by utilizing the converters of HVDC, PV and wind turbines
- Development of tools for situation awareness and dynamic security assessment
- Development of algorithms for preventive and corrective actions
- Increased utilization of stochastic approaches in power system design, planning and operation

Thank you for your attention!