Impact on Power System Stability

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Power System Stability

- „Stability“ - general definition:

  Ability of a system to return to a steady state after a disturbance.

- Small signal effects
- Large signal effects (nonlinear dynamics)

- **Power System Stability - definition according to CIGRE/IEEE:**
- Rotor angle stability (oscillatory, transient-stability)
- Voltage stability (short-term, long-term, dynamic)
- Frequency stability

Power System Stability – Global vs. local stability

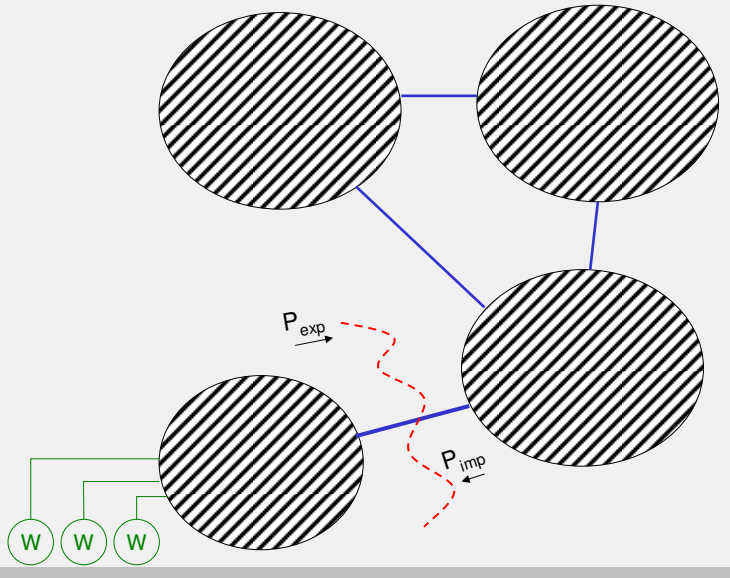
Local effects:

- Loss of synchronism of an individual generator.
- „Run-away“ condition of induction generators.
- Trip of wind generators due to voltage sags.

Global effects:

- Loss of synchronism between network areas -> islanding
- Inter-area oscillations with insufficient damping
- Frequency drop -> excessive load shedding
- Voltage collapse -> system blackout

Wind Generator Impact on Inter-Regional Transfer Limits



Limitation of Inter-Regional Power Transfers

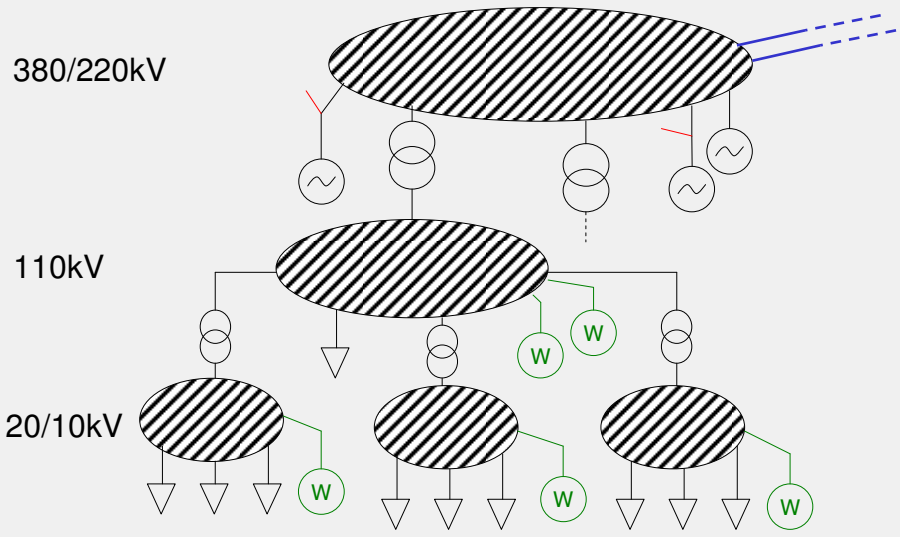
Power Export:

- Thermal Limits of Tie-Lines
- Transient Stability
- Oscillatory Stability (Damping)

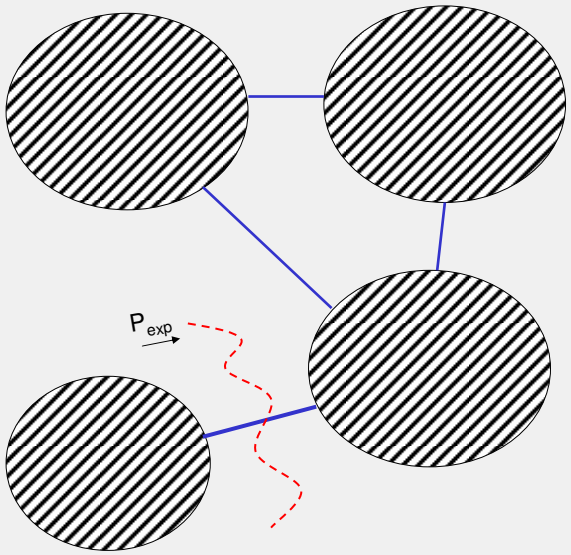
Power Import:

- Thermal Limits of Tie-Lines
- Voltage Stability (especially Generator Outage)
- Frequency Stability (Islanding)

Power Systems with High Level of Wind Generation



Power Export



Power Export – Transient Stability

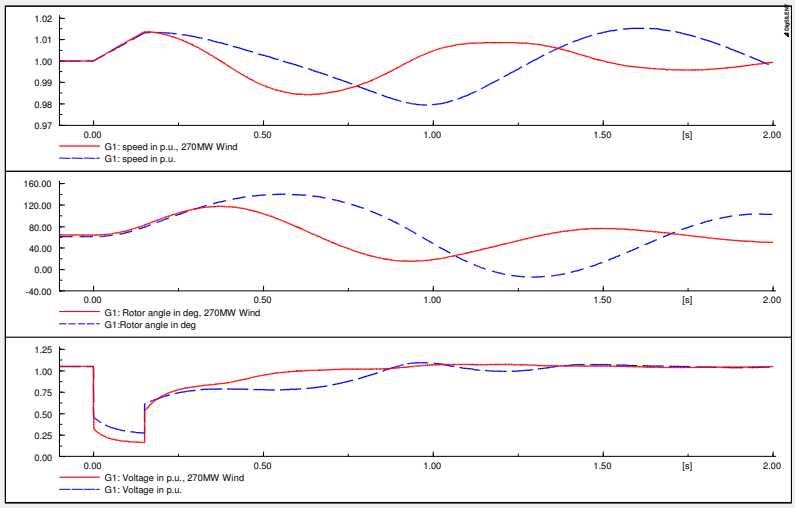
What is different with wind generation?

- Different generator technology.
- Connection to lower voltage levels.
- Larger average distances between synchronous generation.

Influence on Export-Limit?

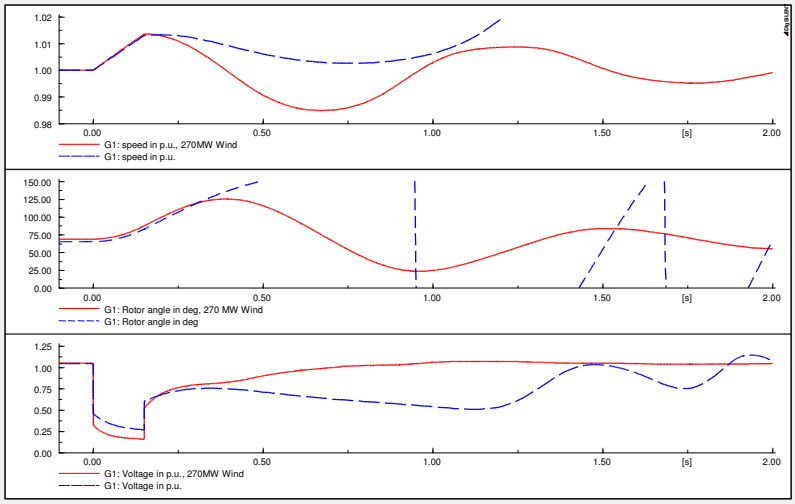
Power Export – Transient Stability

Simulation, Pexp=90MW



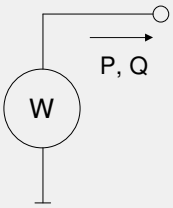
Power Export – Transient Stability

Simulation, Pexp=180MW



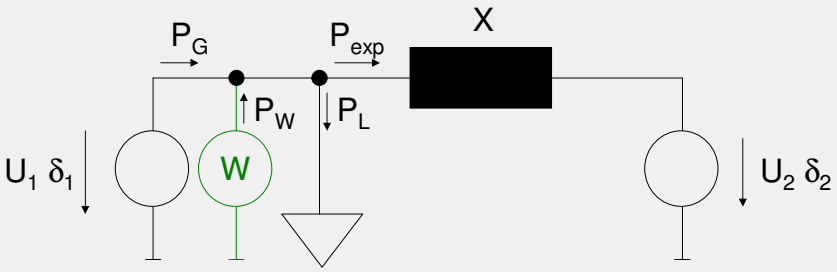
Transient Stability and Wind Power – Basic Considerations

- Wind generator modelling as „static generator“, assuming:
  - P-control
  - Q-control



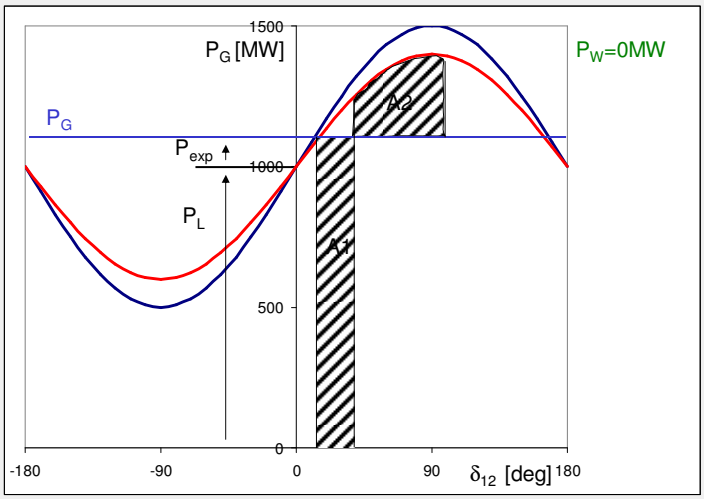
- Aggrupation of all wind generators in one region

Power Export – Transient Stability

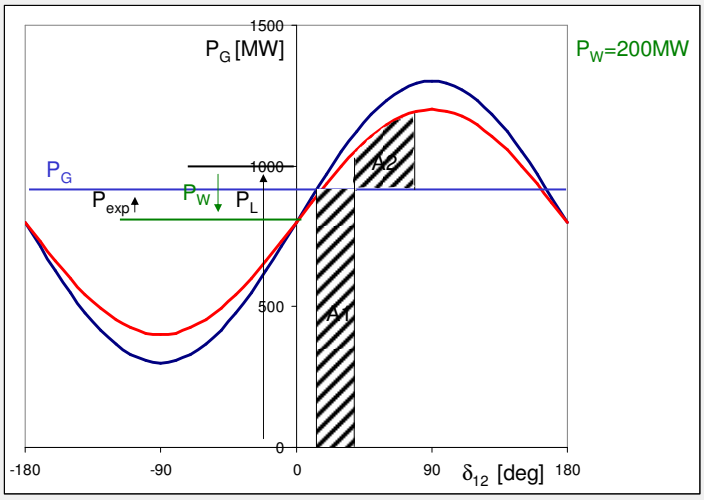


$$P_G = P_L - P_W + P_{\exp} = P_L - P_W + \frac{U_1 U_2}{X} \sin \delta_{12}$$

Power Export – Transient Stability



Power Export – Transient Stability



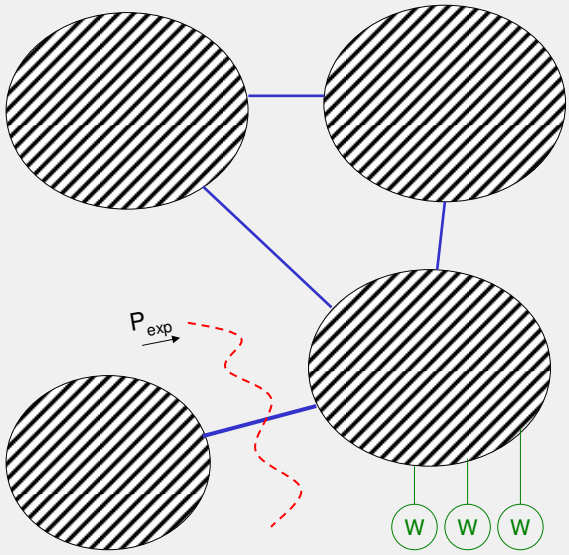
Power Export – Transient Stability

„Static“ generator technology increases transient stability limits:

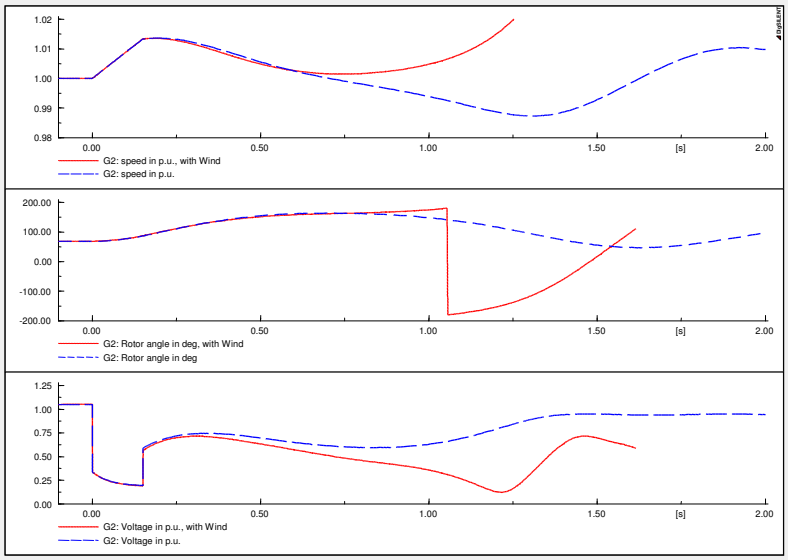
- Kinetic energy is reduced because less synchronous generators are connected to the grid.
- Rotor angle deviation during fault remains almost constant because acceleration time constant referred to total synchronous generation has not changed.
- Result: area A1 small, „room“ für A2 remains unchanged -> Increase of transient stability limits.

Limits of Inter-Regional Power Flows

Case 2



Power Export – Transient Stability



Power Export – Transient Stability

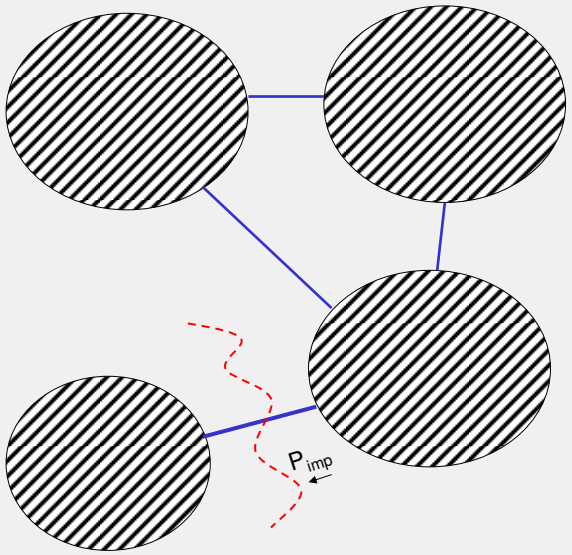
Positive:

- Lower level of kinetic energy increase during fault.
  -> Increase of transient stability export limits.
  -> Improved voltage recovery.

Negative:

- Larger voltage dip during fault.
- Dynamic reactive power reserve reduced because of missing voltage control capability and connection to subtransmission areas.
- Increase of average distance between synchronous generation, higher transfer impedances.

Power Import – Voltage Stability

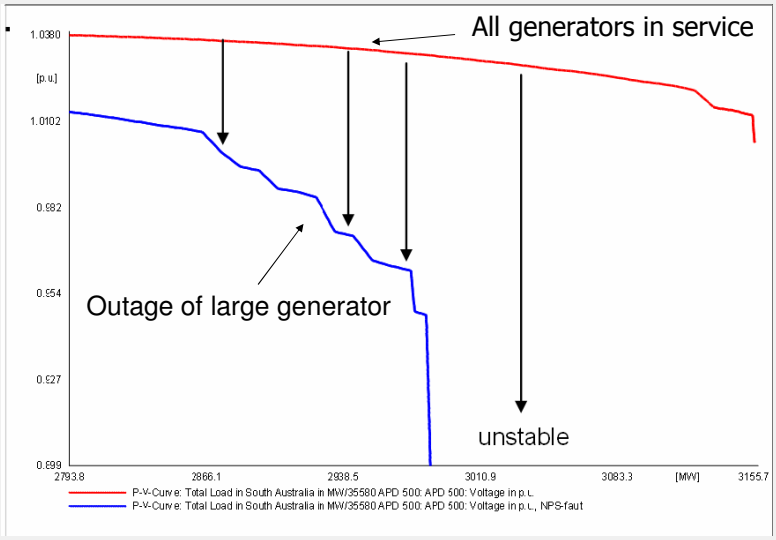


Long-Term vs. Short-Term Voltage Stability

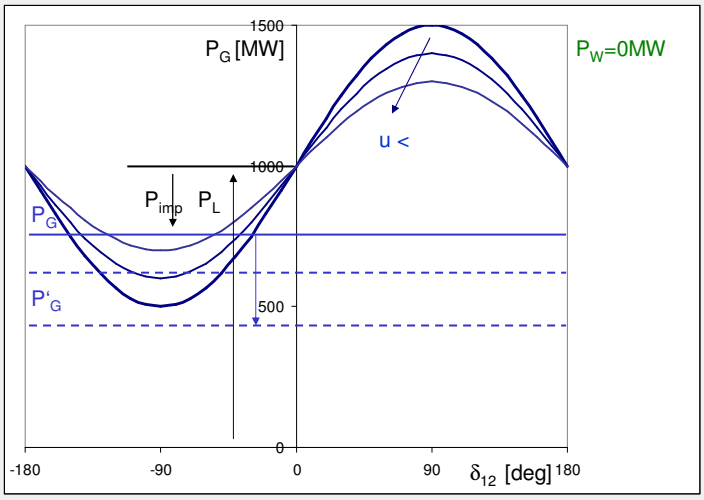
Reactive power control:

	Short-Term	Long-Term
Q- contribution of synchronous gen.	Large (thermal overload capabilities)	Limited by overexcitation limitors
Switchable shunts	No contribution (switching times too high)	High contribution
SVC/TSC	High contribution	High contribution

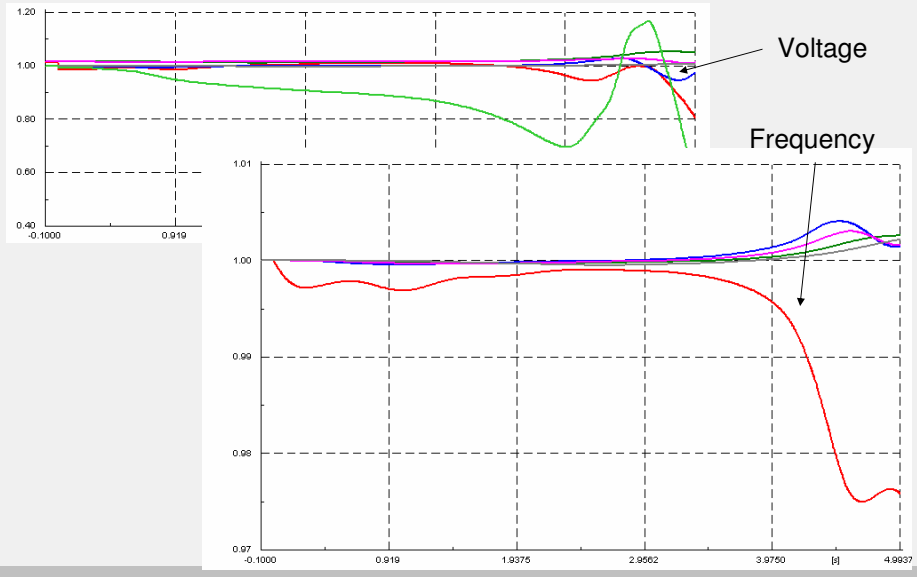
Power Import – Voltage Stability



Power Import – Generator Outage



Short-Term Voltage Instability

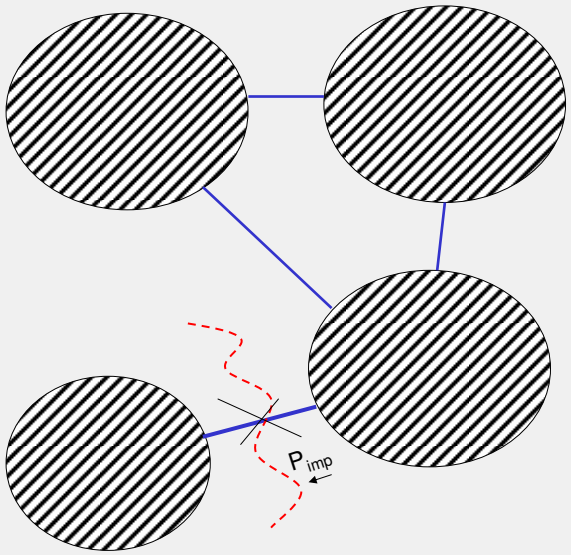


Power Import – Generator Outage – Wind Generator Impact

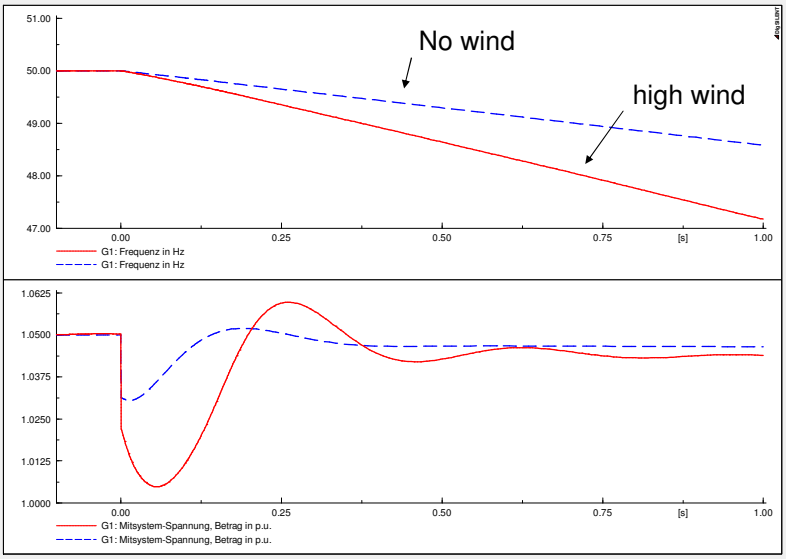
Wind generator impact on voltage stability:

- Basically no influence of „static generation“ on voltage stability limits.
- Reduced reactive power reserves shifts the system closer to voltage stability limits.
- Unreliabile active power output of wind mills amplifies generator outage problem (cascading outages).

Power Import - Islanding



Power Import – Islanding – Frequency Stability



Power Import – Islanding

Islanding results in frequency stability problems (P_{imp}=0):

$$J\dot{\omega} = \frac{P_G + P_{imp} - P_{el}}{\omega}$$

- Total generation (synchronous+wind) remains constant.
- Inertia J reduced.
- Consequence: Frequency drops faster -> increased load shedding

- Possibly voltage problems because of reduced reactive power reserve in the „island“.
- Power reduction of wind generators following to low voltages can make the situation worse.

Wind Generator Impact on System Stability - Conclusions

Wind generation has:

- Positive influence on transient stability constrained export limits.
- Negative impact on voltage stability constrained import limits if:
  - Reactive reserves are lowered -> additional SVCs, SynCons requried.
  - Unreliable power output -> „low voltage ride-through capability“ required

- Negative impact on frequency drops in case of islanding during power import.

Related Studies

- DENA/Deutschland:
  „Energiewirtschaftliche Planung für die Netzintegration von Windenergie in Deutschland an Land und Offshore bis zum Jahr 2020“
  EWI-Konsortium (EWI, E.ON., Vattenfall, RWE, DEWI), 2005

- NEMMCO/Australien:
  „Assessment of Potential Security Risks due to High Levels of Wind Generation in South Australia”
  DIgSILENT GmbH, 2005