Wind Generator Modelling for Fault Ride-Through Studies

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Wind Generator Modelling
General Concepts

Wind Generator Modelling – General Concepts

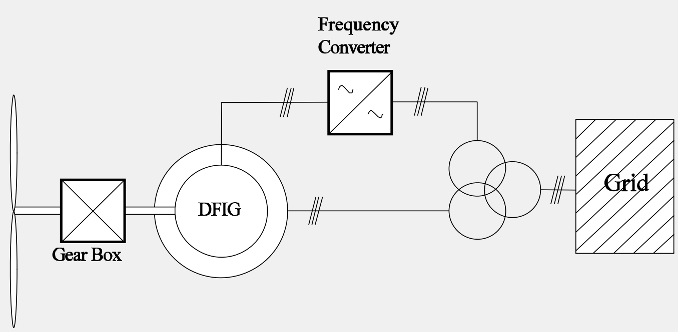
Main functional blocks of a wind generator:

- Generator
- AC/DC converters with electrical controllers.
- Converter protection
- Other protection (over-/undervoltage, overspeed, over-/under-frequency etc.)
- Speed controller.
- Mechanical drive train
- Aerodynamic turbine characteristic
- Pitch controller

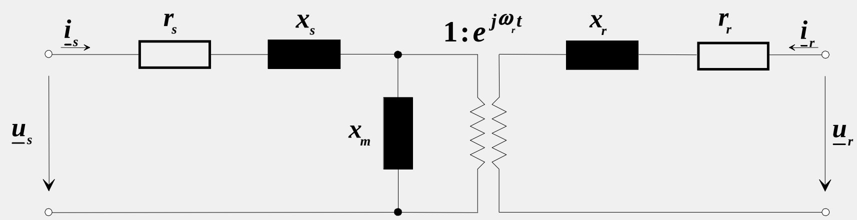
Required accuracy for stability studies:

- Generator/converter/controllers/protection: high
- Mechanical drive train: medium
- Speed controller/Pitch controller/Aerodynamics: low

Doubly-Fed Induction Generator



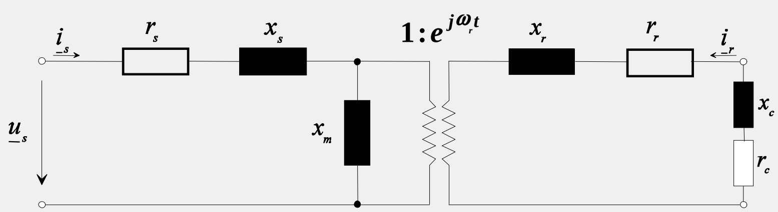
Doubly-Fed Induction Generator



$$\underline{u}_s = r_s \underline{i}_s + \frac{d\underline{\Psi}_s}{\omega_n dt} + j\frac{\omega_{ref}}{\omega_n}\underline{\Psi}_s$$

$$\underline{u}_r = r_r \underline{i}_r + \frac{d\underline{\Psi}_r}{\omega_n dt} + j\frac{\omega_{ref} - \omega_g}{\omega_n}\underline{\Psi}_r$$

DFIG with Crow Bar Inserted



$$\underline{u}_s = r_s \underline{i}_s + \frac{d\underline{\Psi}_s}{\omega_n dt} + j\frac{\omega_{ref}}{\omega_n}\underline{\Psi}_s$$

$$\underline{0} = (r_r + r_c)\underline{i}_r + \frac{d\underline{\Psi}_r}{\omega_n dt} + j\frac{\omega_{ref} - \omega_g}{\omega_n}\underline{\Psi}_r$$

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Model Reduction

- Neglecting stator transients (3rd order model):

$$\underline{u}_s = r_s \underline{i}_s + j\frac{\omega_{ref}}{\omega_n}\underline{\Psi}_s$$

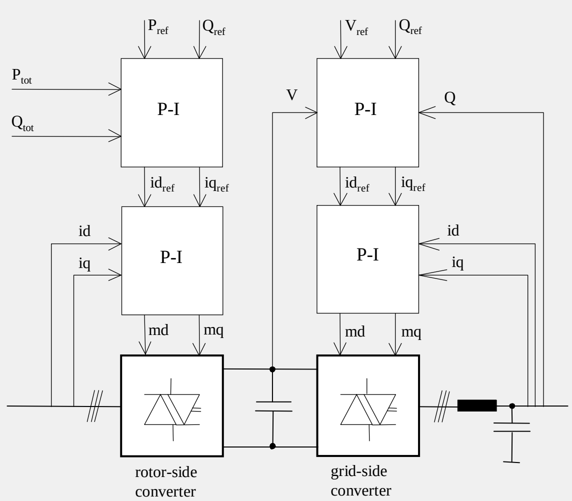
$$\underline{u}_r = r_r \underline{i}_r + \frac{d\underline{\Psi}_r}{\omega_n dt} + j\frac{\omega_{ref} - \omega_g}{\omega_n}\underline{\Psi}_r$$

- Neglecting rotor transients (1st order model):

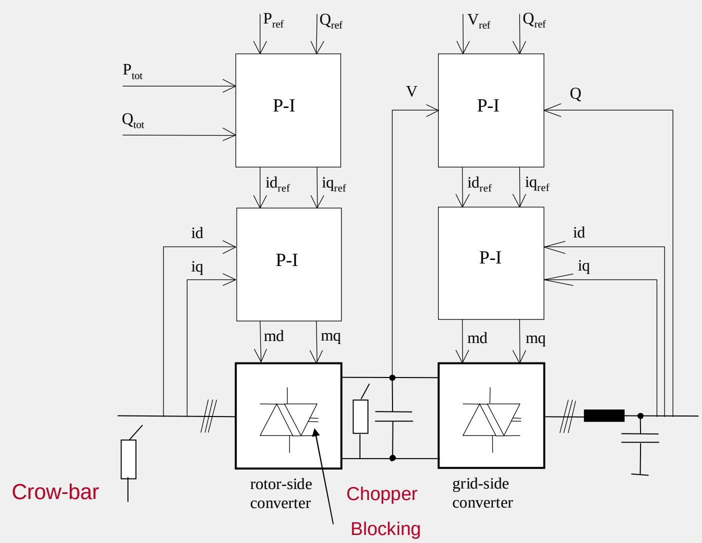
$$\underline{u}_s = r_s \underline{i}_s + j\frac{\omega_{ref}}{\omega_n}\underline{\Psi}_s$$

$$\underline{u}_r = r_r \underline{i}_r + j\frac{\omega_{ref} - \omega_g}{\omega_n}\underline{\Psi}_r$$

DFIG-Control



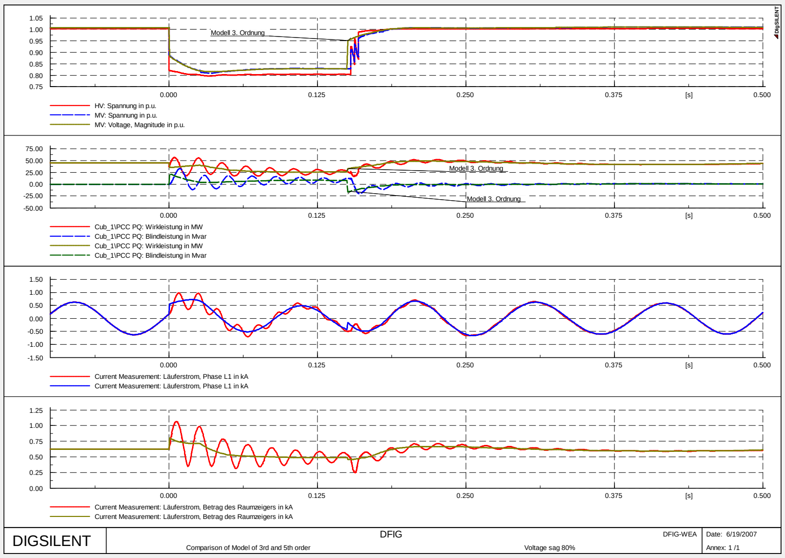
Protection of Rotor-Side Converter



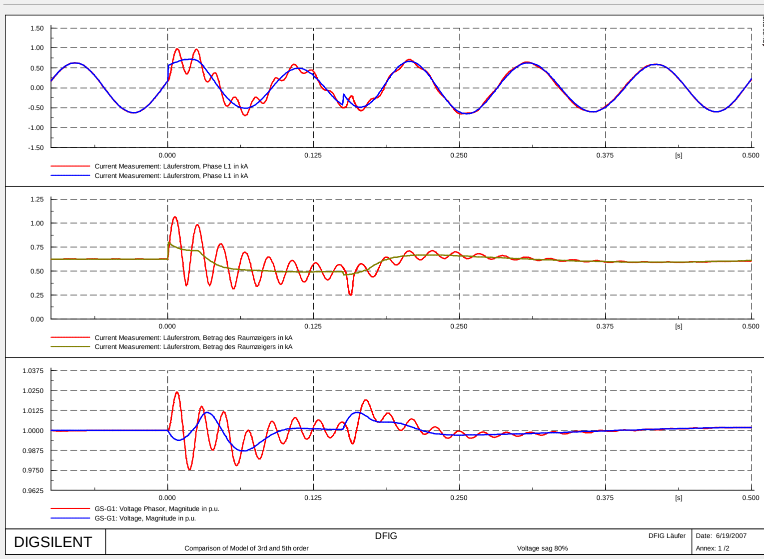
Converter Protection

- Protection against:
  - High DC-voltages
  - High rotor currents
- Chopper resistance -> protects against high DC-voltages
- Crow-bar -> protects against high DC-voltages and/or high rotor currents

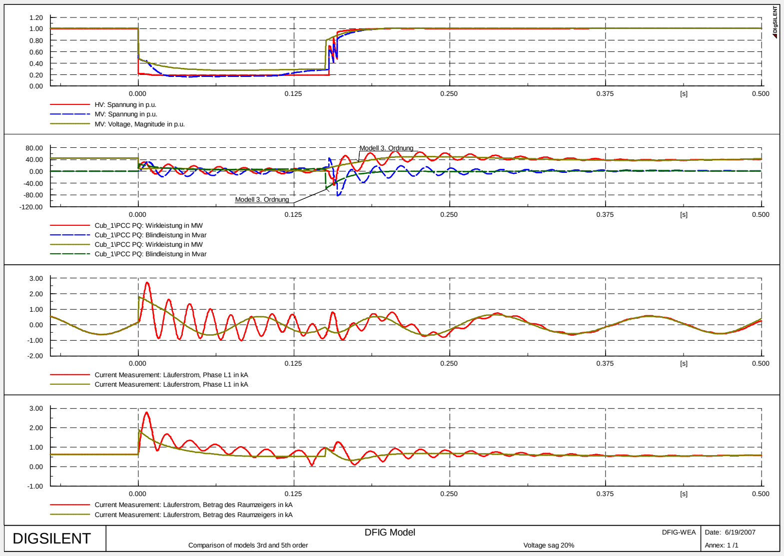
Example: symmetrical Voltage Dip, 80%



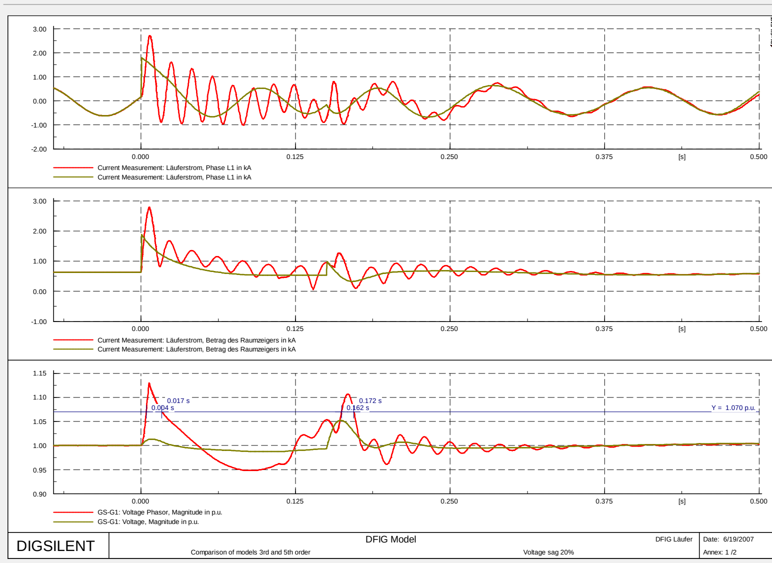
Example: symmetrical Voltage Dip, 80%



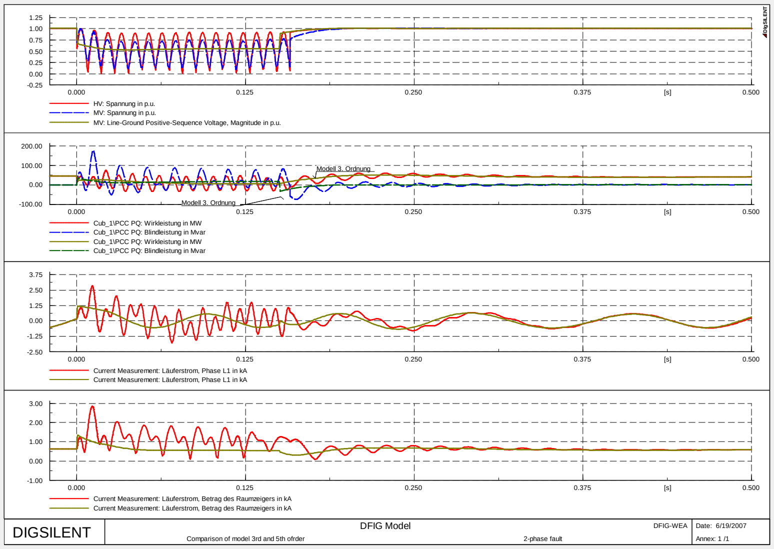
Example: symmetrical Voltage Dip, 20%



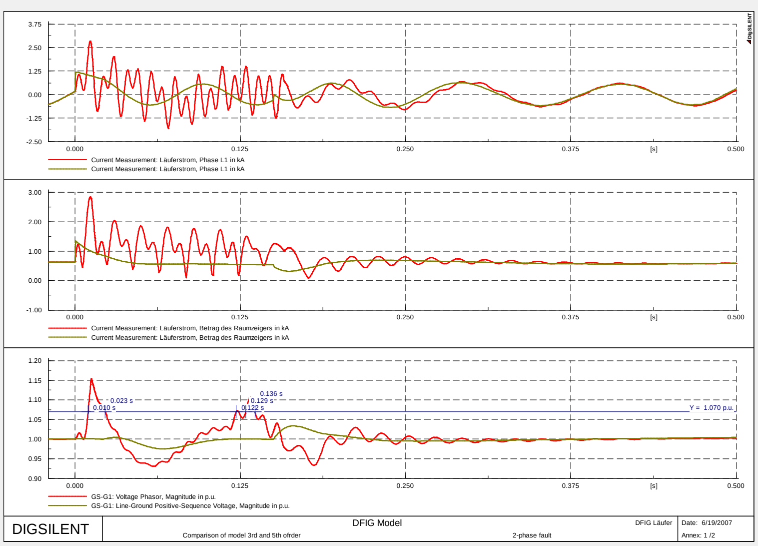
Example: symmetrical Voltage Dip, 20%



Example: 2-phase fault



Example: 2-phase fault



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Discussion

- “Stability model” (model of 3rd order) produces results with sufficient accuracy if rotor converter protection doesn’t trigger.
- But: “Stability model” (model of 3rd order) is not able to predict max. rotor currents and max. DC-voltage correctly, hence it cannot predict rotor protection action.
- Crow-bar insertion has substantial influence on voltage support during fault and hence on fault ride-through capability of a wind farm.

Conclusion

- For analysing fault ride through capability of DFIGs, detailed EMT models are required.
- PowerFactory allows modelling a wind farm by an EMT model (typical step-size 0,1 ms) and the rest of the system (e.g. NEM-system) by a stability (RMS)-model (typical step size 10ms)
- Approach has successfully been applied in wind farm integration studies in Australia (e.g. Cape Bridgewater)
- For stability impact studies, studying large number of wind-farms, simplified “stability model” is sufficient.

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