Transients in Offshore HVDC-systems

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DTU Electrical Engineering
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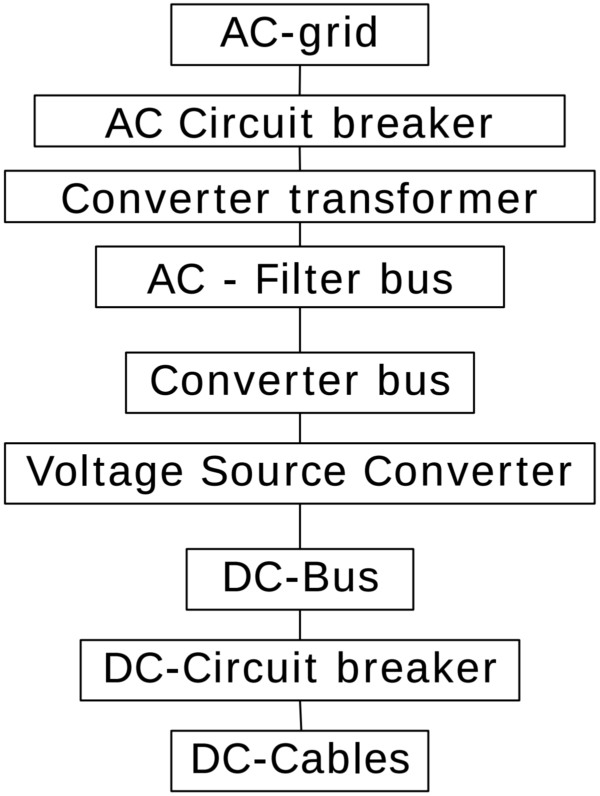
Transients in offshore HVDC systems, an approach

- Point-to point systems
- Switching and fault situations, Classical approach, Low frequent models
- Multiterminal systems
- Offshore/onshore
- Challenges
- Discussion, Focus?

The components of a ½ point-to point system



The system in question

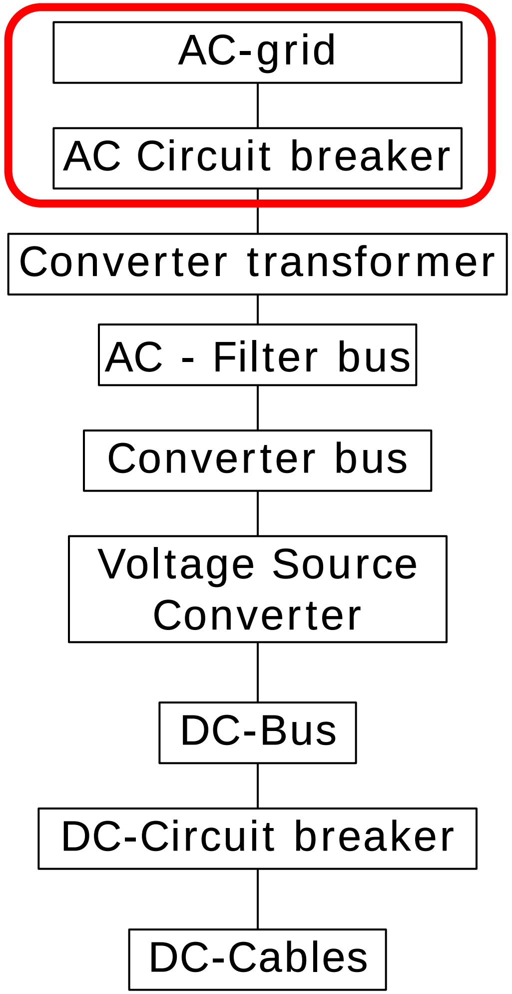
- Bipolar point-to-point HVDC-system
- Converter technology based on Voltage Source Converters(VSC)
- Offshore system – cable-based system
- HVDC-circuit breaker has been implemented
- The transformer configuration of the VSC-stations are star/delta-configurations
- Power frequency range (=models) on AC side

Multi-terminal HVDC-systems

- Although the HVDC-system about to be presented is a point-to-point connection, the emphasis of this project will be on transients in multi-terminal HVDC-system.
- However only very little attention has been given to this area of research at this point. Therefore, it will be interesting to see how the known transients, from point-to-point systems affect multi-terminal systems.

AC-breaker

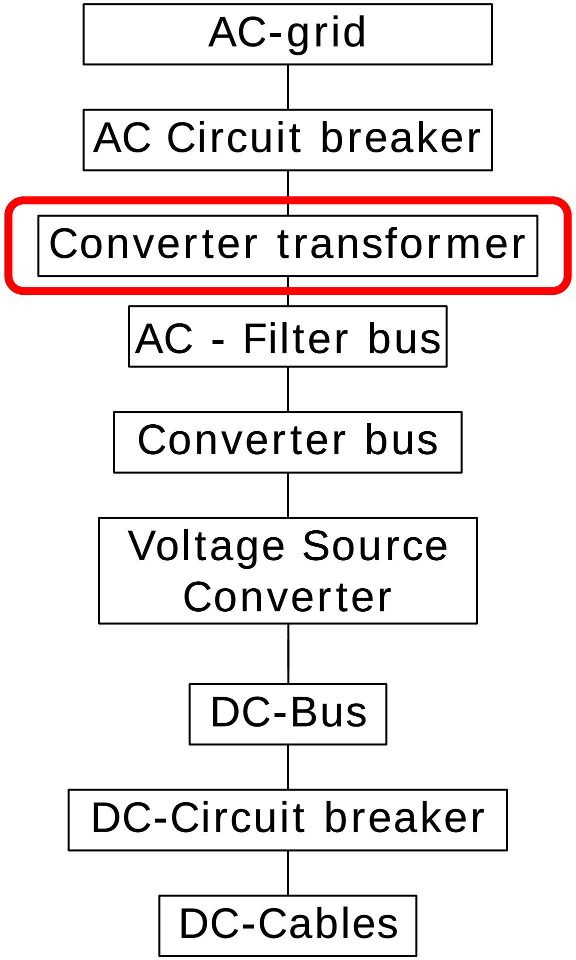
- Transients due to load swirching or clearing of AC-faults[1]
- Transients arise when discharged capacitors placed near the converter are charged after fault clearing [1]
- This transient could affect the system even more seriously if resonance exist between the filter capacitor and the grid[1]



Converter transformer

- Line-to-ground fault on the converter side of the transformer cause an overvoltage in the converter of 1.5pu[2]

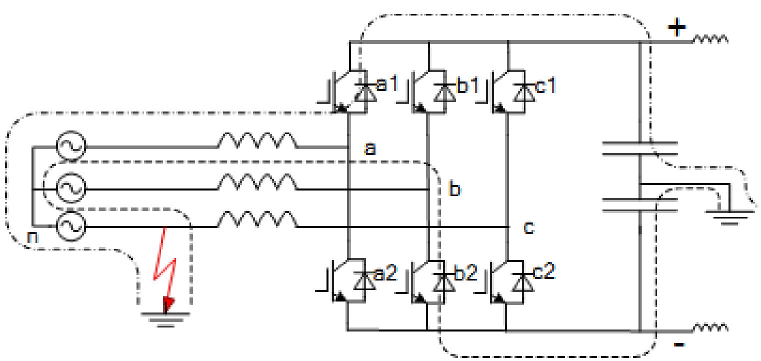
- Line-to-line fault



AC-filter bus

- Line-to-ground fault, overcurrent handled by phase reactors, initiates blocking of both rectifer and inverter, voltage of adjacent lines increase by 1.73[1]

- Line-to-line fault, overvoltage but no overcurrent[1]



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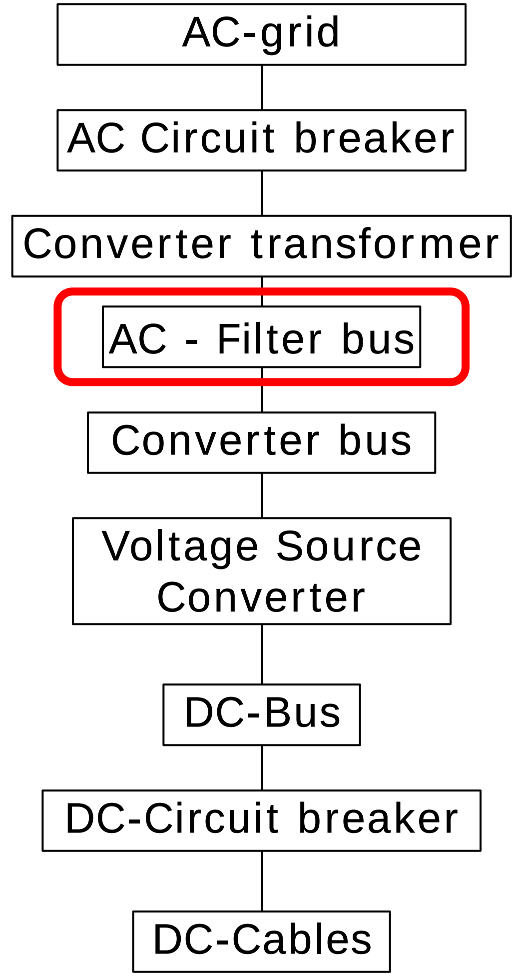
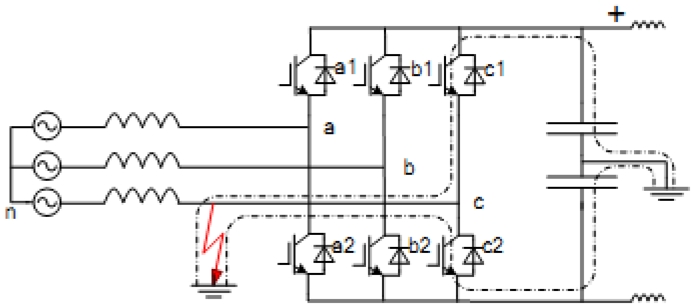


Converter bus 1

- Line-to-ground fault results in discharge of DC-capacitor causing overcurrent through the VSC, rapid rise of current in the affected phase[1]



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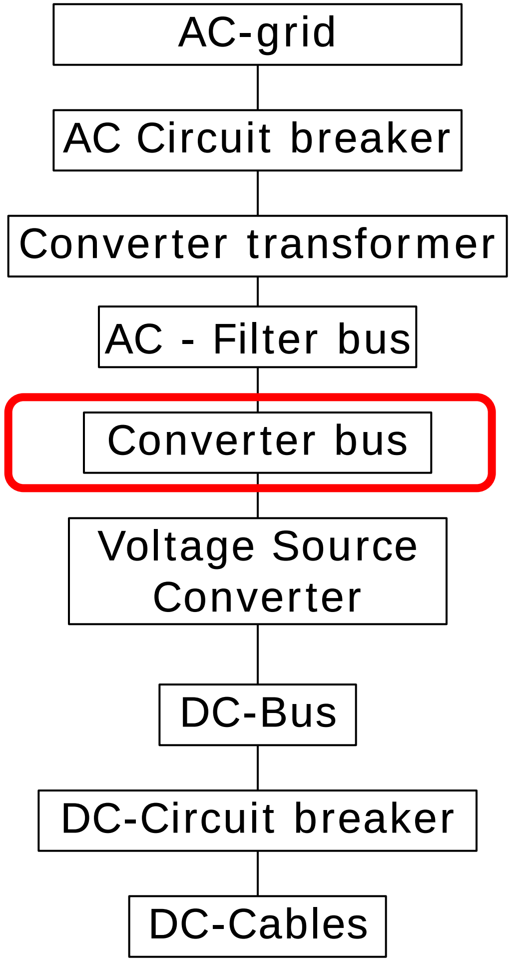
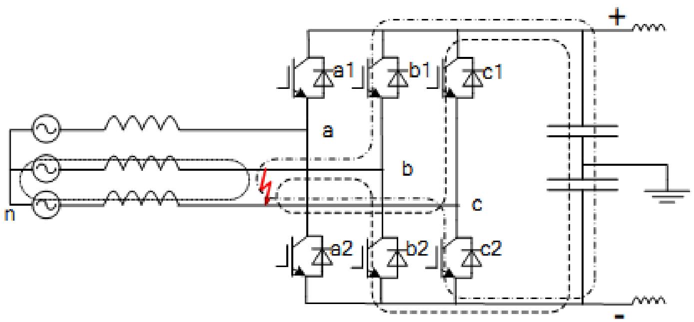


Converter bus 2

- Line-to-line fault, no overvoltage – phase reactors and converter transformer will be exposed to short-circuit current[1]



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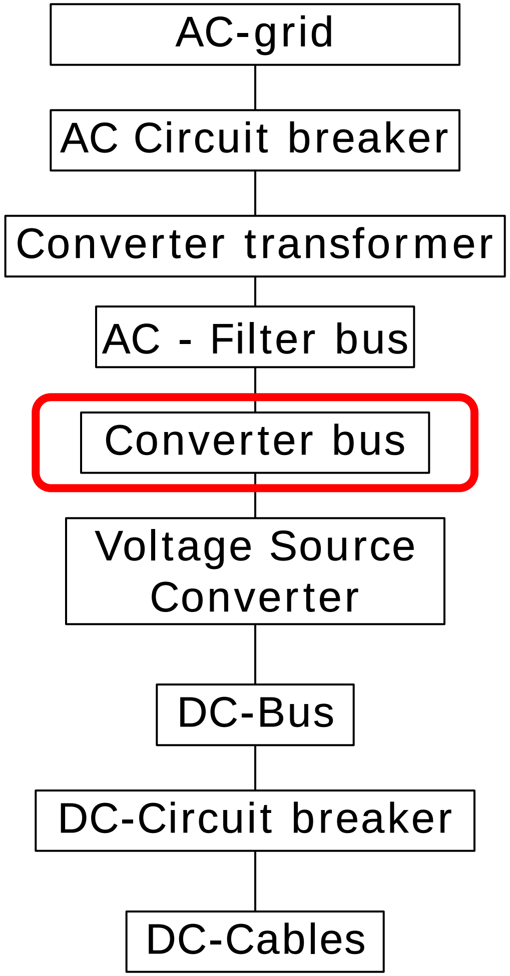
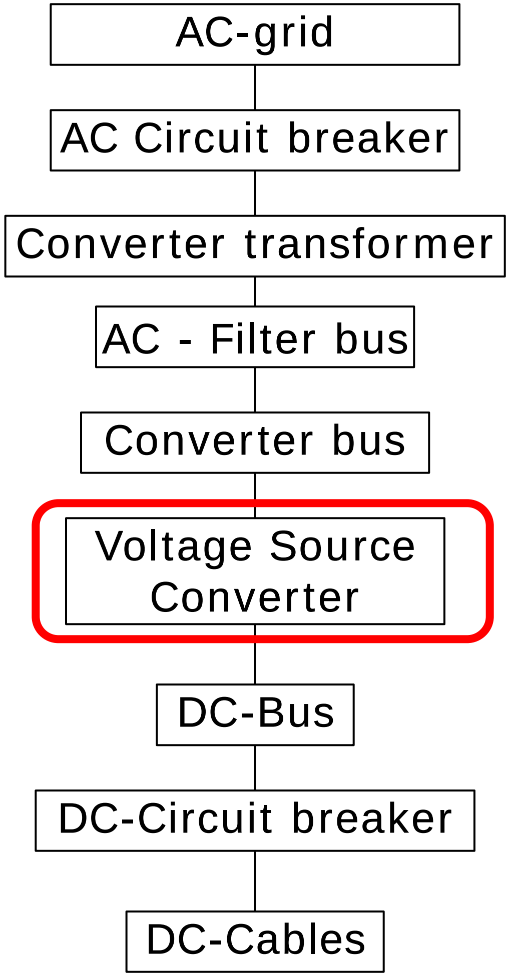


Voltage source converters 1

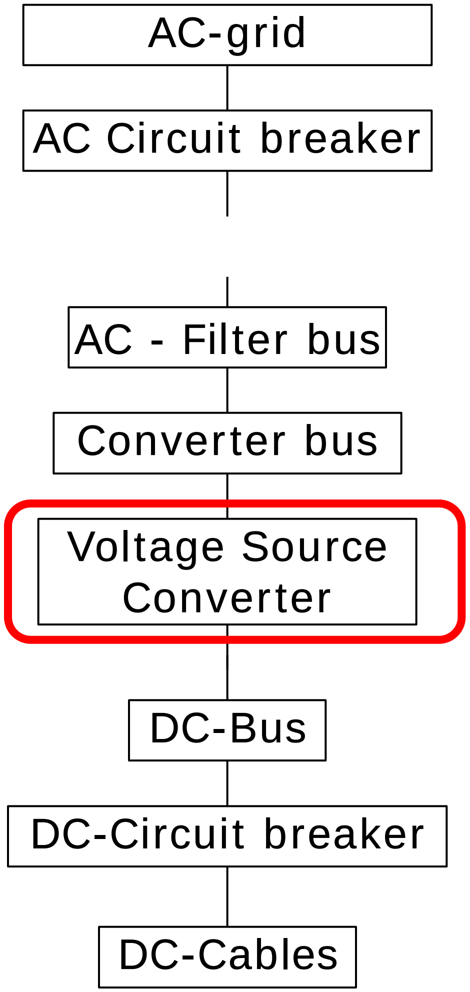
- Negative-sequence voltage - ripples on DC-bus voltage, only rectifier affected, can be prevented by applying the star/delta transformer configuration[3]
- Load rejection or loss of voltage control - overvoltages at DC capacitor[1]
- Mis-fire[1]



Voltage source converters 2

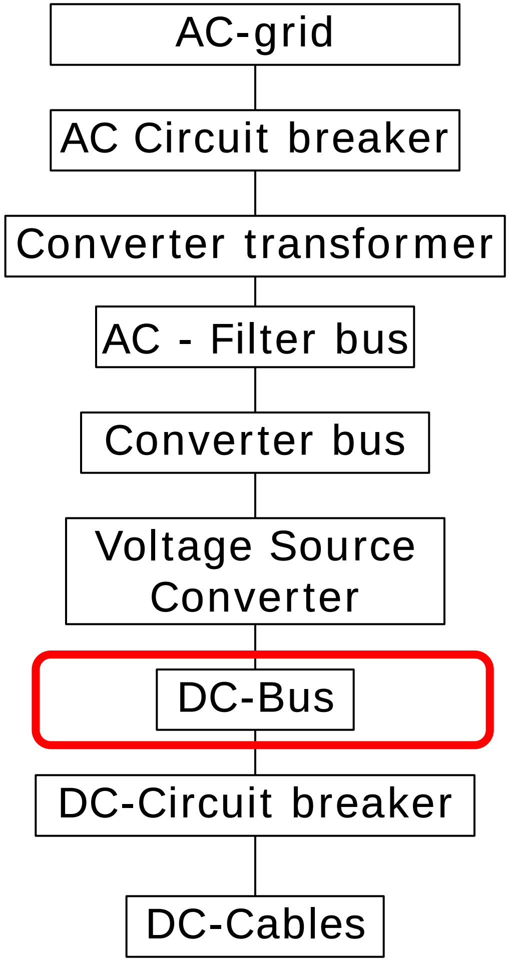
- Blocking of the inverter due to ground fault causes overvoltage, as the rectifier keeps on feeding power, until it senses the overvoltage[1]

- In multiterminal systems when a fault on a line occurs, the VSCs at either end will be blocking, hence the fault current will be drawn from the capacitors of the adjacent VSCs [4]



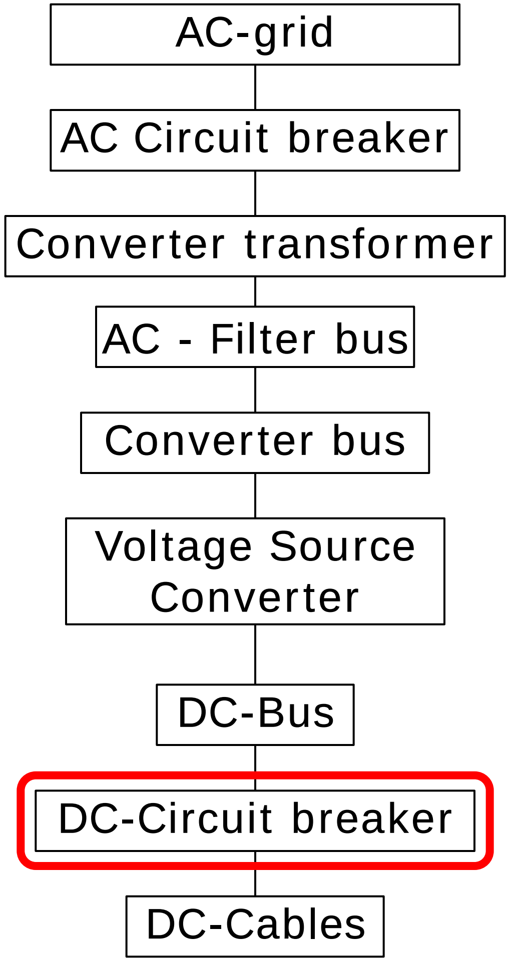
DC bus fault

- Not a fault necessarily occuring at the bus itself, but generally faults occuring between the converter and the DC bus [5]
- Ground fault occuring close to the DC-capacitor, most serious fault if DC-capacitor already charged to the arrester protective level [1]



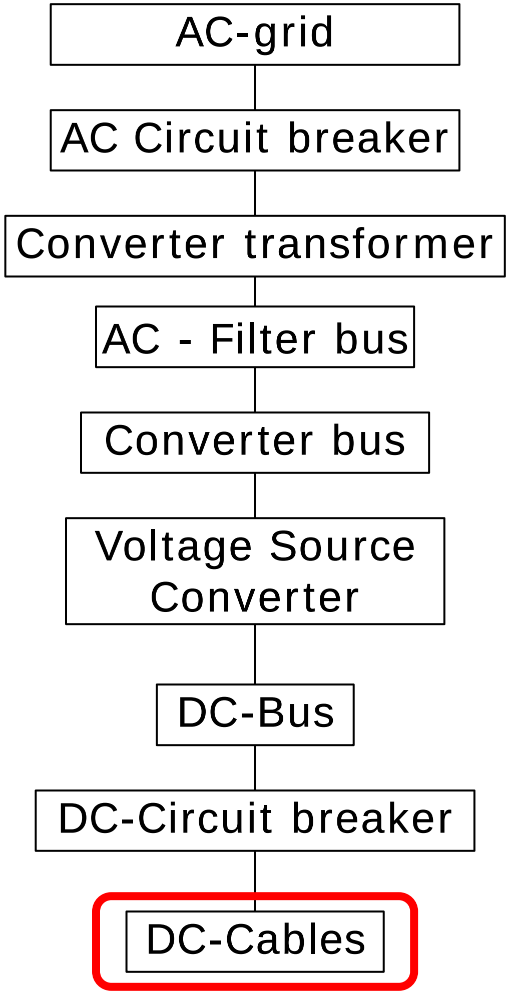
DC-Circuit breaker

- In multiterminal systems, transients occur when the 2 breakers at either end of the line are closed almost simultaneously, leading to a high-voltage being present between the contacts of the second DC circuit breaker [6]
- Complex procedure in order to break a fault current [6]
- Fast DC-switches, can only be closed when the DC voltages on both sides match[7]



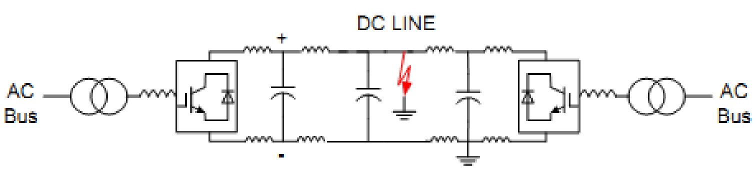
Cable faults 1

- Positive-line-to-ground fault [4]
- Negative-line-to-ground fault [4]
- In either of the above cases the voltage of the unaffected pole will increase to 2 pu. [4]
- Line-to-Line fault [4]
- Fault current dependent upon the location of the fault, since the current is dependent upon the inductance of the cable which is proportional to the length of the cable [4]



Cable faults 2

- A special case is when the converter is earthed at one side, a line-to-ground fault will produce a short-circuit current, but not an overvoltage. The short-circuit current will be provided by the AC-grids at either of the line[1]



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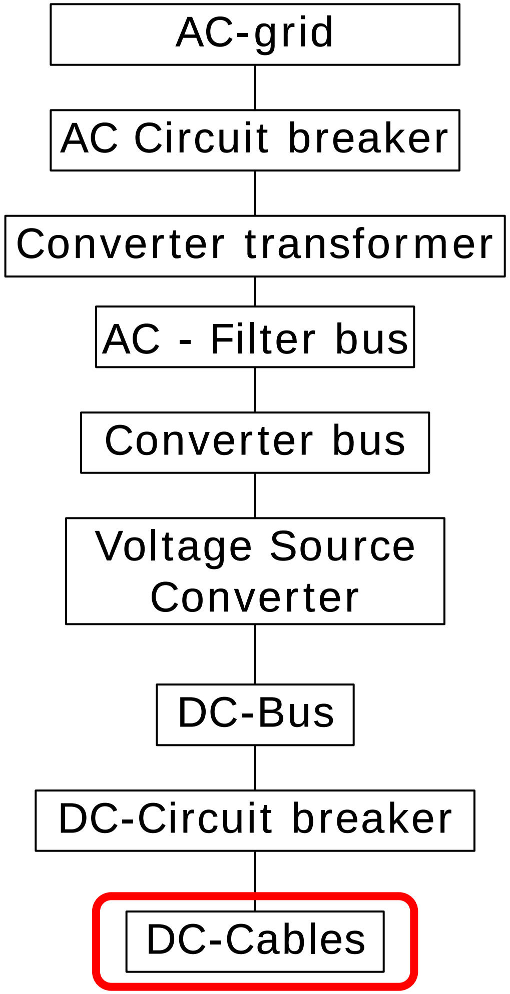
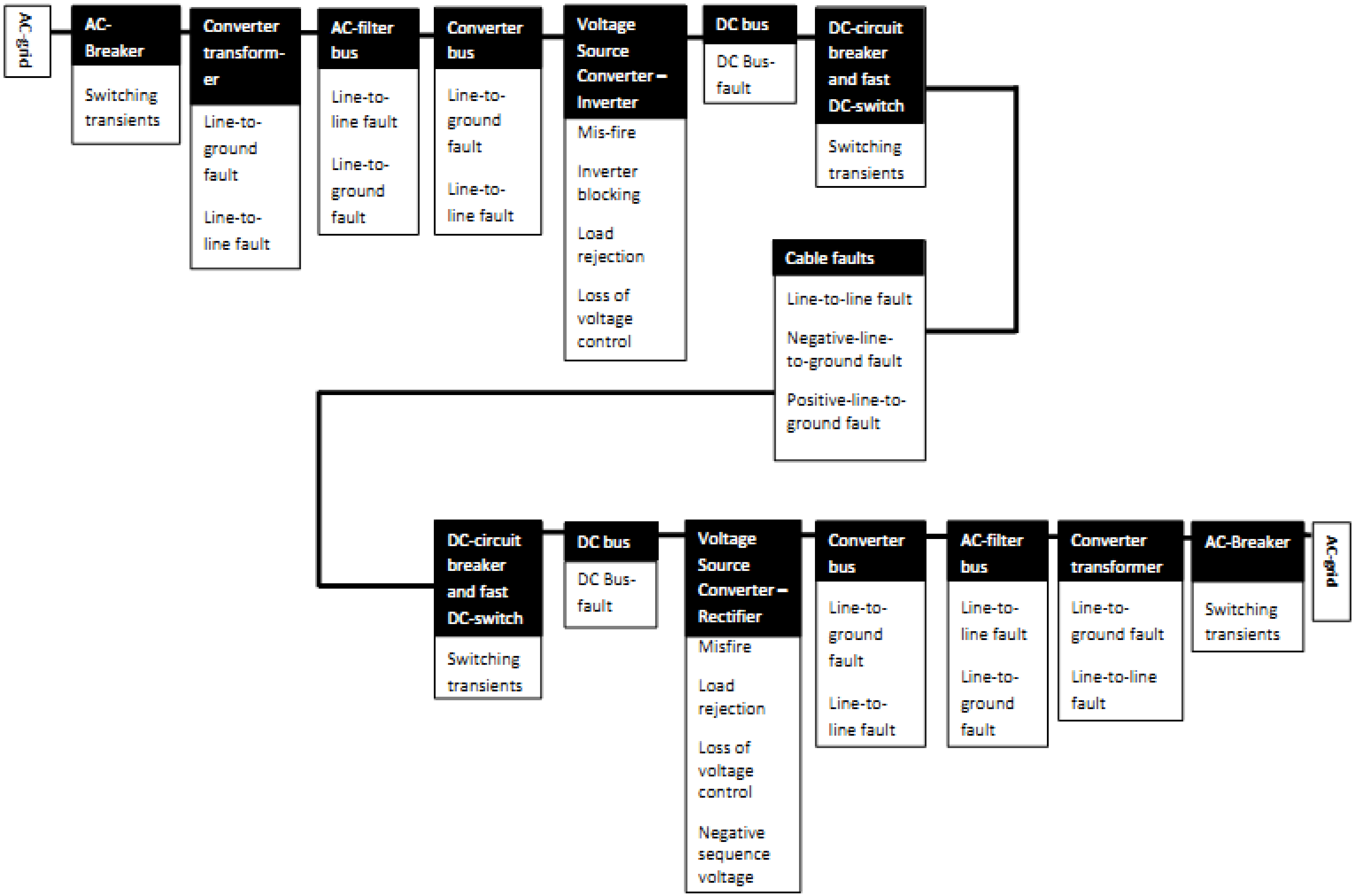
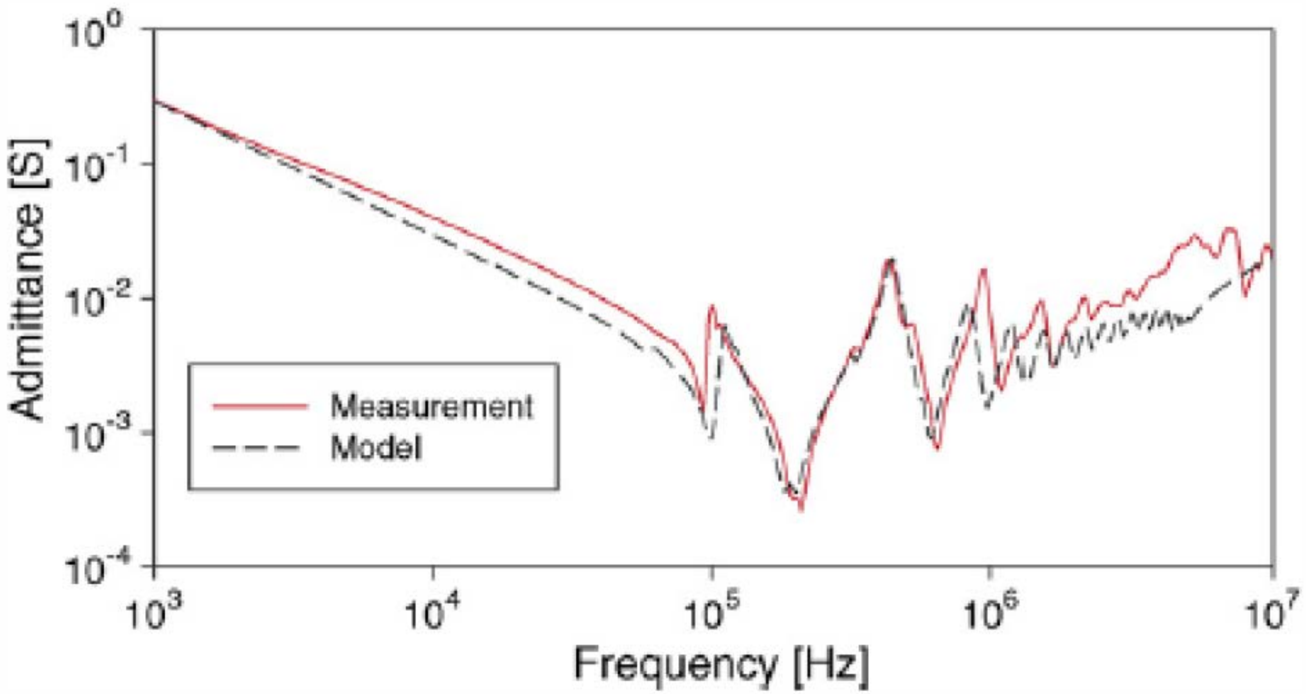


Point-to-point HVDC-system

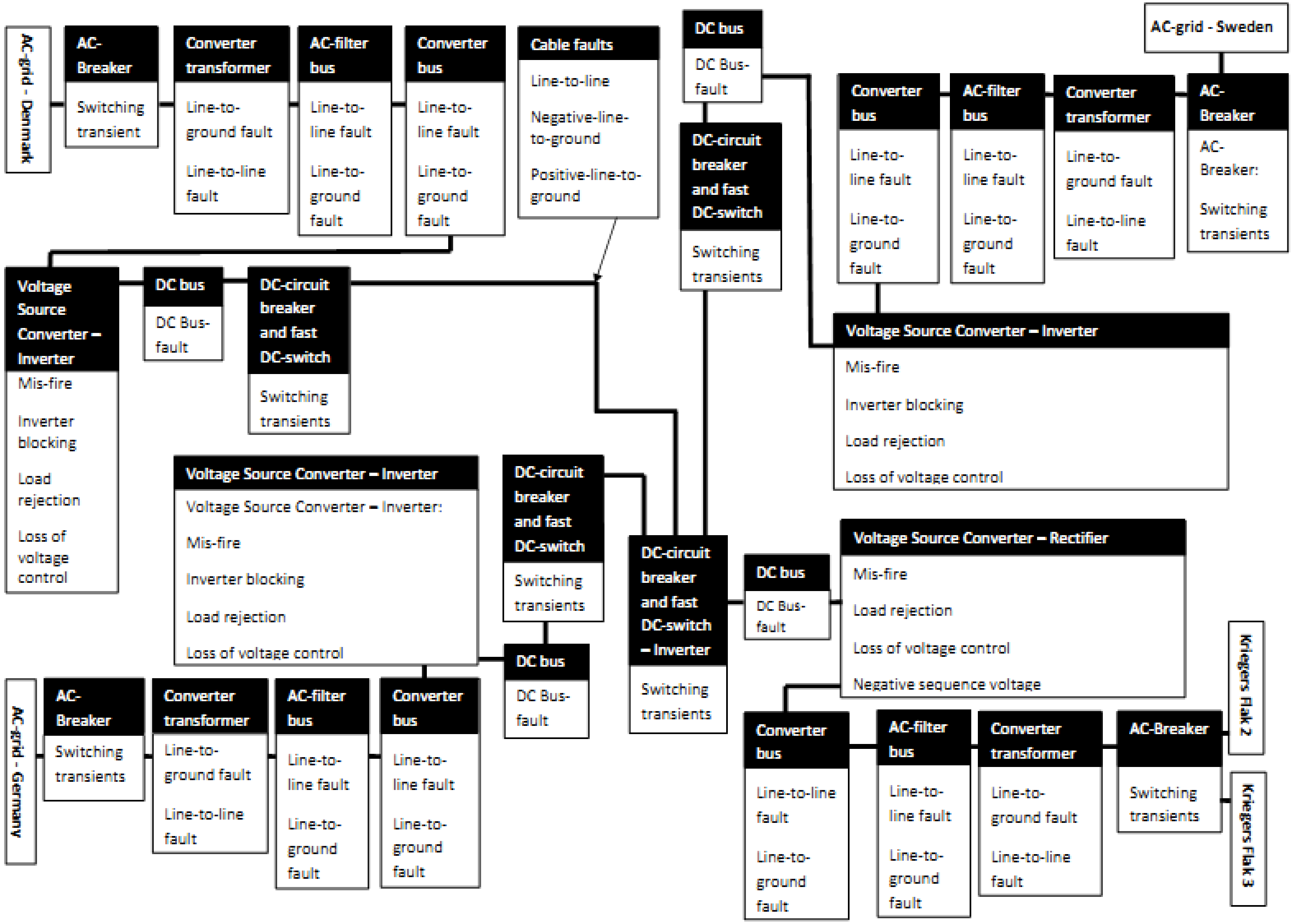


The complete picture?

- Low frequency range
- Faults and fault current breaking can cause fast transients
- Component models change to broad band models
- Example
  Transformer:



Another challenge: VSC Multi-terminal HVDC-system (Here Kriegers flak)



Challenges, concluding

- Transient events point-to-point vs. Multiterminal
- Offshore: long cables, but no lightning
- Broad band models
- DC breaker models
- Time domain simulations
- Verification difficult so far

References 1

- [1] Components Testing of VSC System for HVDC Applications, Working group B4.48, Cigré technical brochure nr. 447, February 2011
- [2] Tang, Lianxiang; Ooi, Boon-Teck; Managing zero-sequence in Voltage Source Converter; pp. 795 - 802 vol.2, Conference Record of the Industry Applications Conference, 2002, 37th Annual Meeting.
- [3] Yue, Wei; Zhao, Chengyong; Lu, Yi; Li, Gang; Study and Simulation of VSC-HVDC under AC Power System Faults; pp. 1-6, 2010 5th International Conference on Critical Infrastructure(CRIS).
- [4] Tang, Lianxiang; Ooi, Boon-Teck; Protection of VSC-Multi-Terminal HVDC against DC-faults; pp. 719-724, Vol. 2, 2002 IEEE 33rd Annual Power Electronics Specialists Conference, pesc 02.
- [5] Working group B4.37; VSC Transmission; Cigré technical brochure nr. 269; April 2005
- [6] Joint Working Group 13/14.08; Circuit-breakers for meshed multiterminal HVDC-systems – Part II: Switching of transmission lines in meshed MTDC-systems; pp. 63-84, Electra nr. 164, February 1996

References 2

- [7] Tang, Lianxiang; Ooi, Boon-Teck; Loacting and Isolating DC Faults in Multi-Terminal DC systems; pp. 1877-1884; IEEE transactions on Power Delivery, Vol. 22, No. 3, July 2007
- [8] Yang, Jie; Zheng, Jianchao; Tang, Guangfu; He, Zhiyuan; Characteristics and Recovery Performance of VSC-HVDC DC Transmission Line Fault
- [9] An Analysis of Offshore Grid Connection at Kriegers Flak in the Baltic Sea. Joint Pre-feasibility Study By Energinet.dk, Svenska Kraftnät, Vattenfall Europe Transmission, May 2009