Distributed State Estimation of Hybrid AC/HVDC Grids by Network Decomposition

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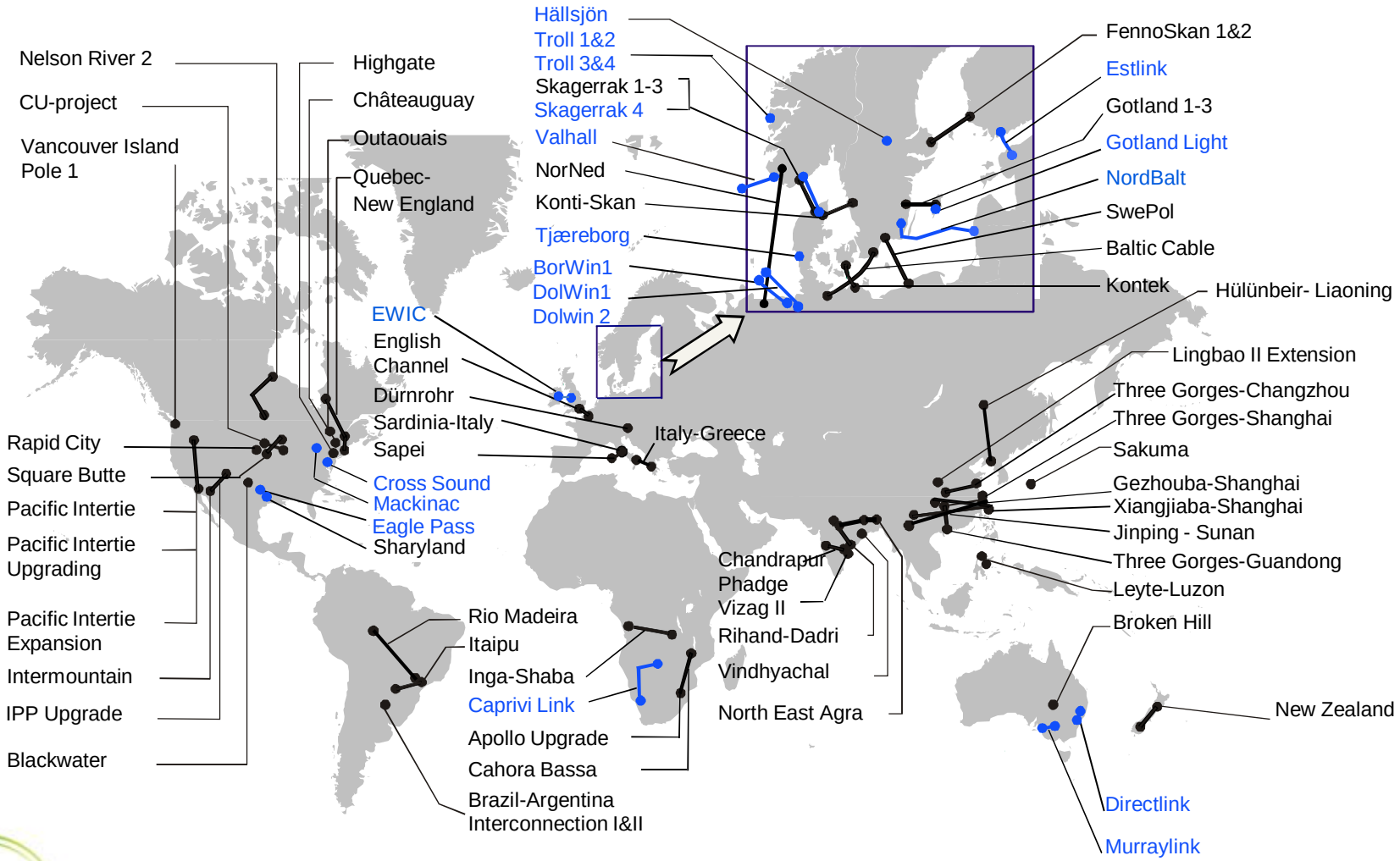
Outline

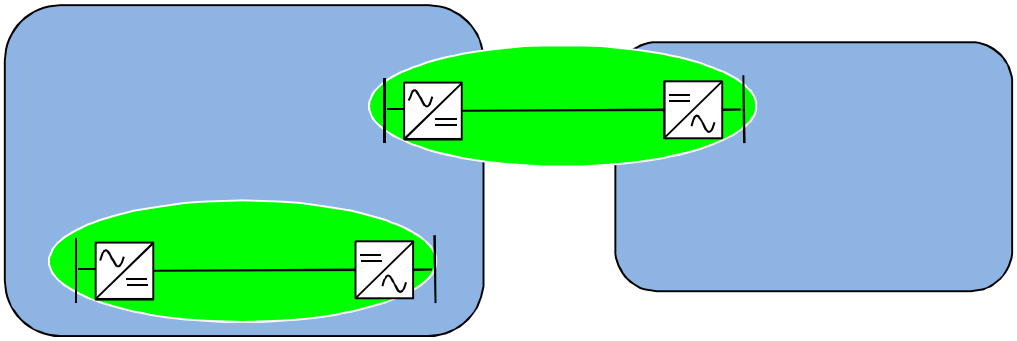
- Evolving power grid technology
- DC Transmission and benefits
- State estimation for the hybrid AC/DC network, & modeling requirements
- Solution approach
- Test result

Numerous HVDC Applications



The evolving power grid

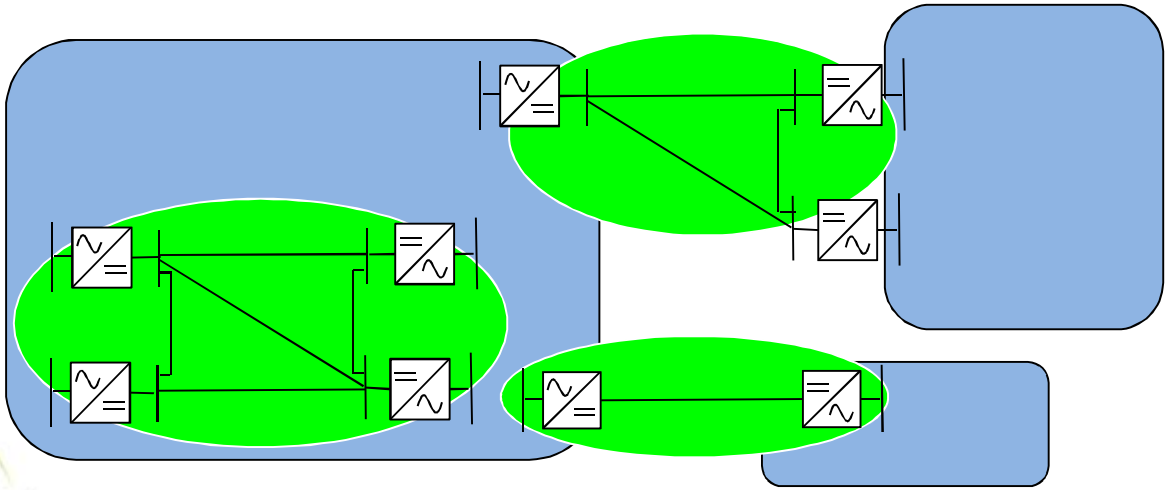
AC grids with P2P (point to point) DC links



DC grid

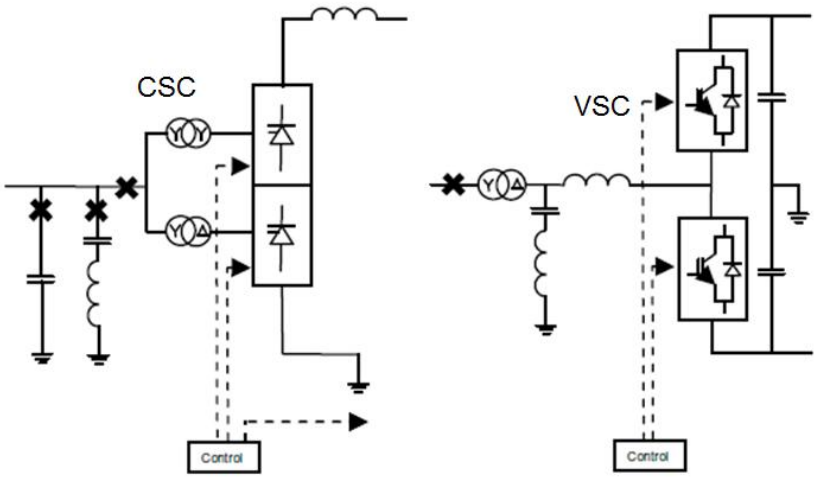
AC grid

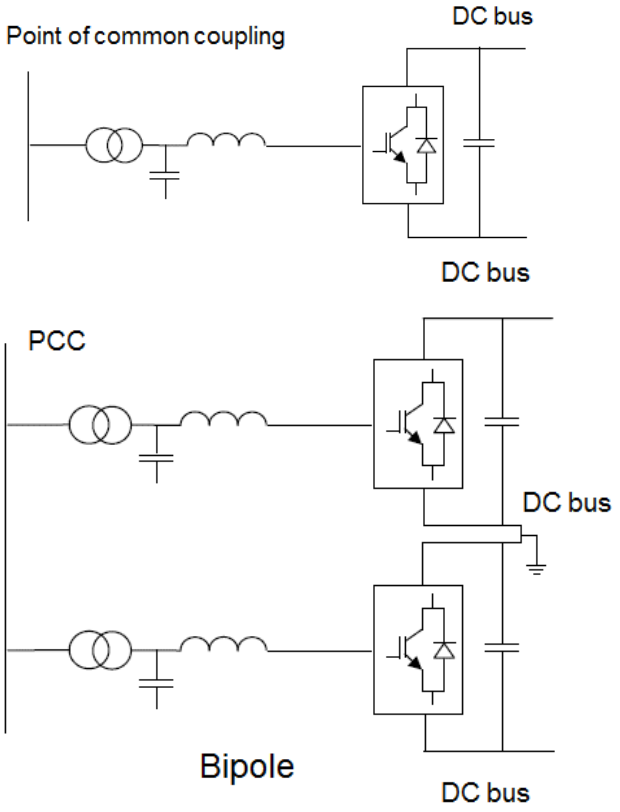
AC grids embedded or interconnected with MTDC grids



HVDC Technology - CSC and VSC HVDC

- CSC – Current source converter, thyrister based
- VSC - Voltage source converter, IGBT based



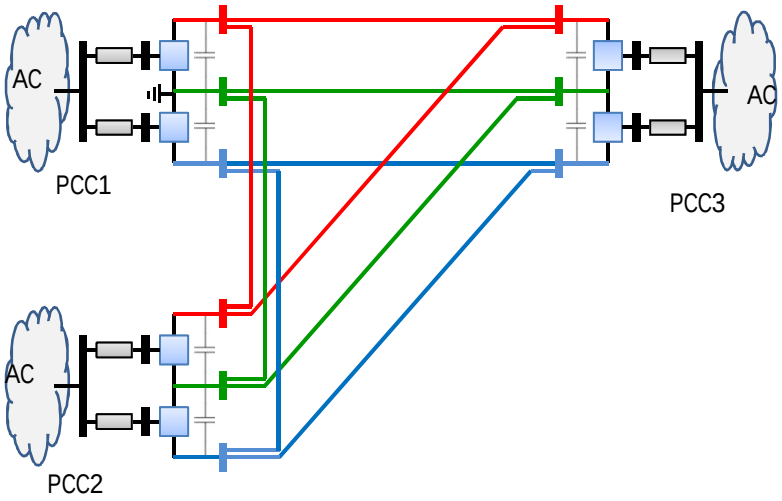


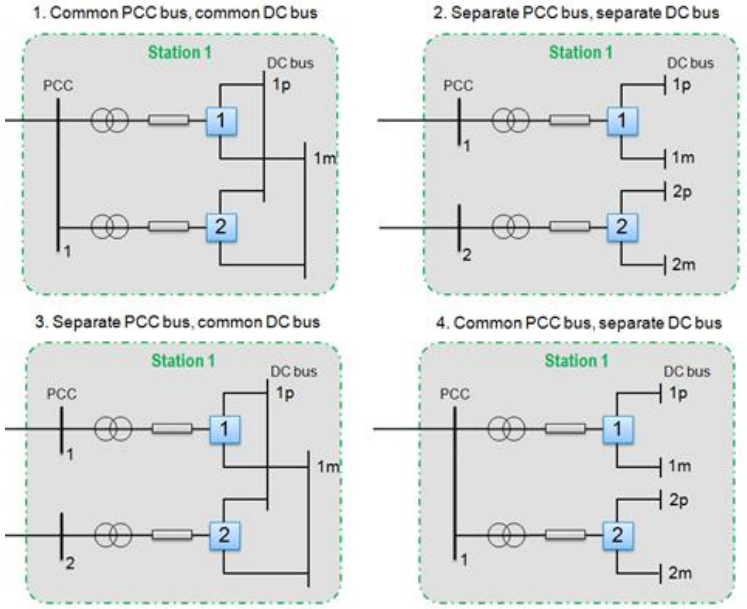
Advantage of DC Transmission

- High power long distances
- Low transmission losses over long distances
- Connection of asynchronous grids
- Full control of P/Q flow (4 quadrant control by VSC)
- Small footprint for HVDC
- Negligible magnetic fields compared with AC

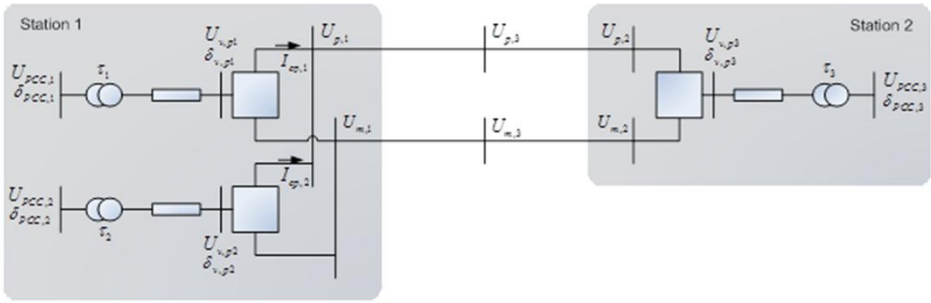
Modeling requirements for MTDC in SE

- Traditional approach for P2P DC modeling lacks generality and details

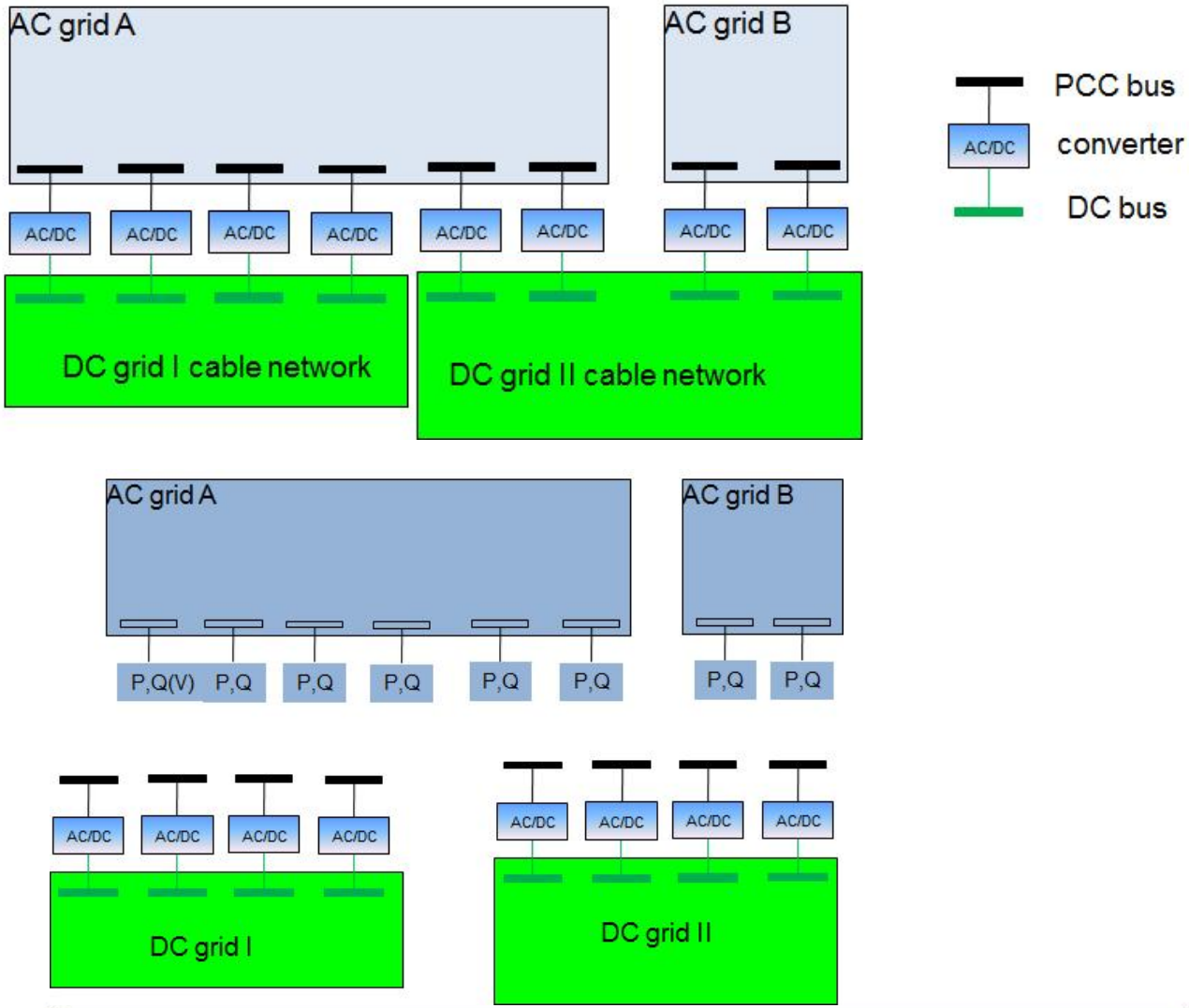




- Transformer/phase reactors
- DC buses & DC cable network/grounding resistors
- AC/DC converters
- Converter station and DC bus configurations
- Converter station operation modes

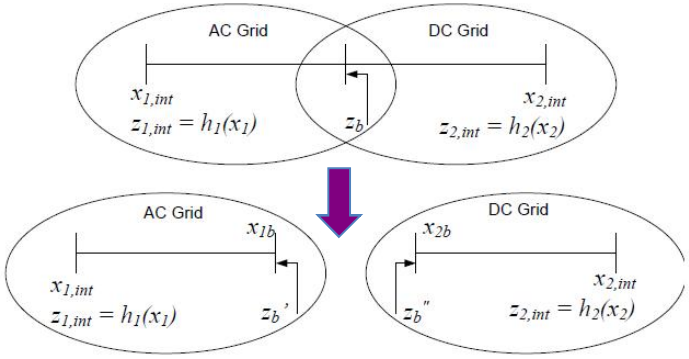


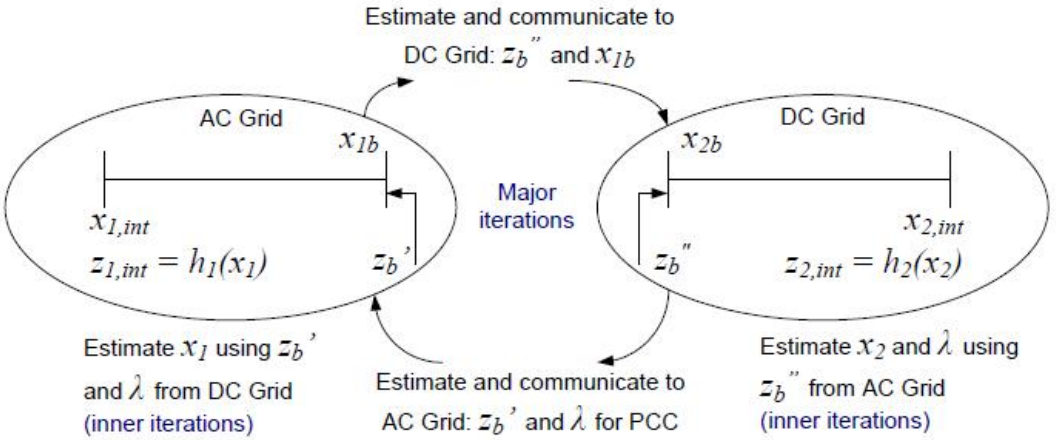
Decoupling AC/DC grids for State Estimation



Solving SE by Decomposition

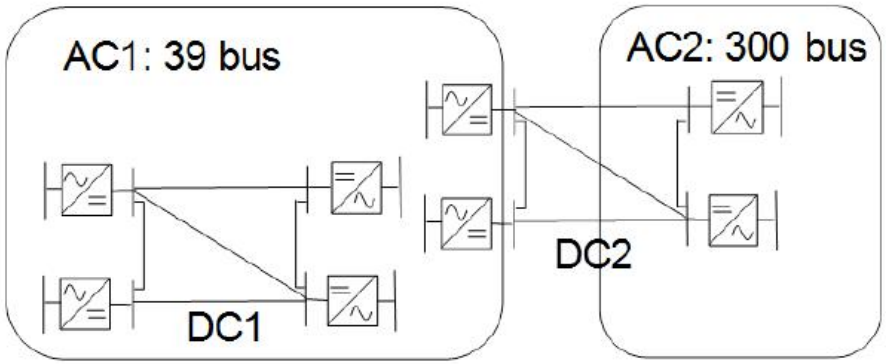
- LaGrangian relaxation to handle PCC bus state uniqueness constraints
- Block wise Gauss-Seidel approach to decouple the equations
- AC grids and DC grids solved by separate SE modules
- Boundary state information exchanged between AC grid and DC grids solvers

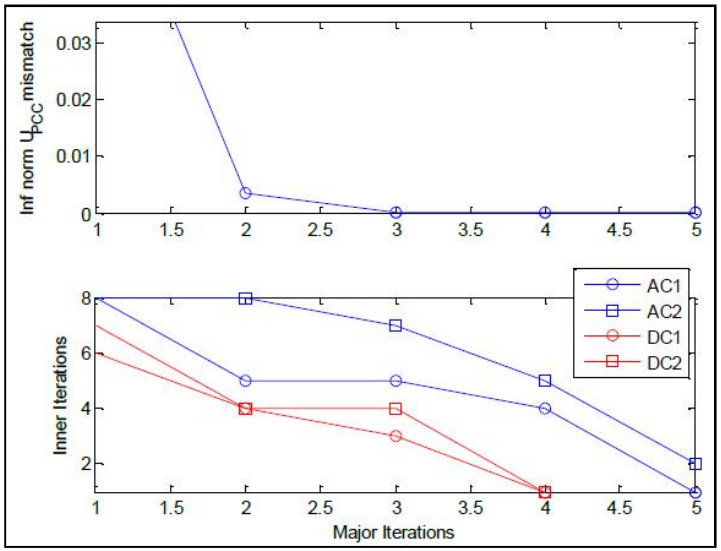




Test Case and results

- Multiple AC Multiple DC system with 2 AC grids, 2 DC grids
  - DCG1: Symm monopole, wind farm connection, parallel converters, converter-less DC bus, cable out
  - DCG2: Bipole, various grounding, one converter is out-of-service
  - Major iterations converge in 5 iterations





Conclusions

- Good convergence characteristics (both outer and inner iterations are low)
- Moderate increase in CPU effort
- Model complexity encapsulation, allowing independent development and upgrade of MTDC converter model, DC grids features