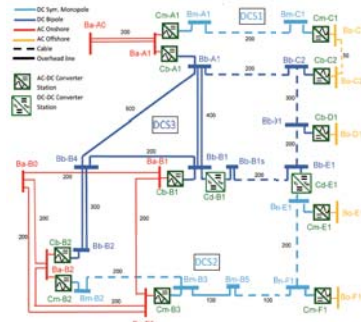


### Taxonomy and Definition of Terms for HVDC Networks

Are we talking about the same thing?

- What is a HVDC network?
  - HVDC grid? HVDC system?
- Multi-terminal HVDC... but what is terminal?
- Meshed HVDC grids... but what is a mesh?
  - Including a series connected DC-DC converter?
  - Connection through an AC station?
  - Connection through an AC cable?
- What is a HVDC hub?
  - What is the difference of hub and node?
  - And a supernode?
- Large HVDC systems... but what does *large* mean?

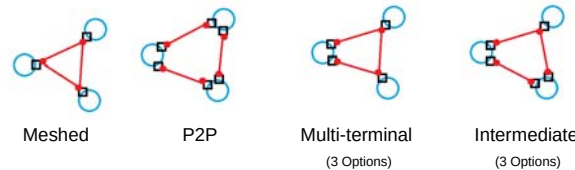


The CIGRE B4 DC Grid Test System

→ Existing taxonomy cannot handle DC-DC converters and supernodes

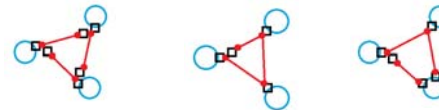
### Optimisation of HVDC Grid Layout

Simple example: Connecting three AC stations with three HVDC cables  
Considering only AC-DC converters:



2 options / AC station →  $2^3 = 8$  options

Considering also DC-DC converters:



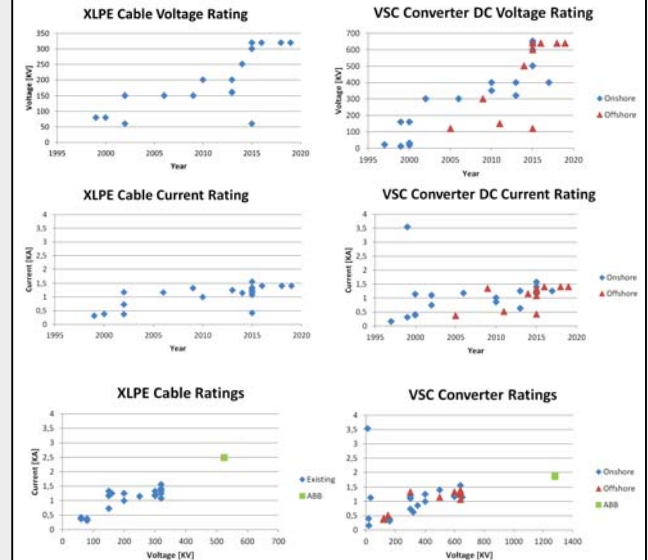
Total: 4 options / AC-station →  $4^3 = 64$  options

4 AC stations → 22 structures + 5 options / AC station → 1513 options  
Considering DC-DC converters → 23 options / AC station → many options

5 AC station → 603 structures + 15 options / AC station → Millions!  
Considering also DC-DC converters → ☠️

A future HVDC grid might easily connect to more than 5 AC stations...  
→ number of options tremendous  
→ challenging to optimise the layout by mathematical means  
→ decisions based on experience and intuition?

### HVDC Technology Development XLPE Cables and VSC Converters



#### Conclusion Voltage

- Voltage ratings increasing quickly, reaching 320 KV 'standard'
- ABB: 525 KV cable + 640 KV converter, satisfactory for super grid

#### Conclusion Current

- Current ratings stagnating at ~1,5 KA, super grid needs more
- Japanese GTO-based VSC 3,5 KA (1999) → MMCs with GTO ?
- ABB: 2,5 KA cable (✓) + 1,9 KA converter (could be a bit more...)
  - 525 KV \* 1,9 KA = 1 GW (Limit in Nordic grid = 1,2 GW)

### Conclusion

- Standardisation of common terms is important for successful communication
- Optimisation of HVDC grid layout is challenging due to a very large number of options
- HVDC technology is on the way, and seems ready for super grids (ABB announcements)

### Future Work

- Acquiring more national project funding to continue Berlin model co-operation
- Finalise taxonomy and definition of terms
- Propose taxonomy for use in CIGRE, CENELEC, e.t.c.