Presented by Les Brand - Convener

Brisbane – 21/11/2019

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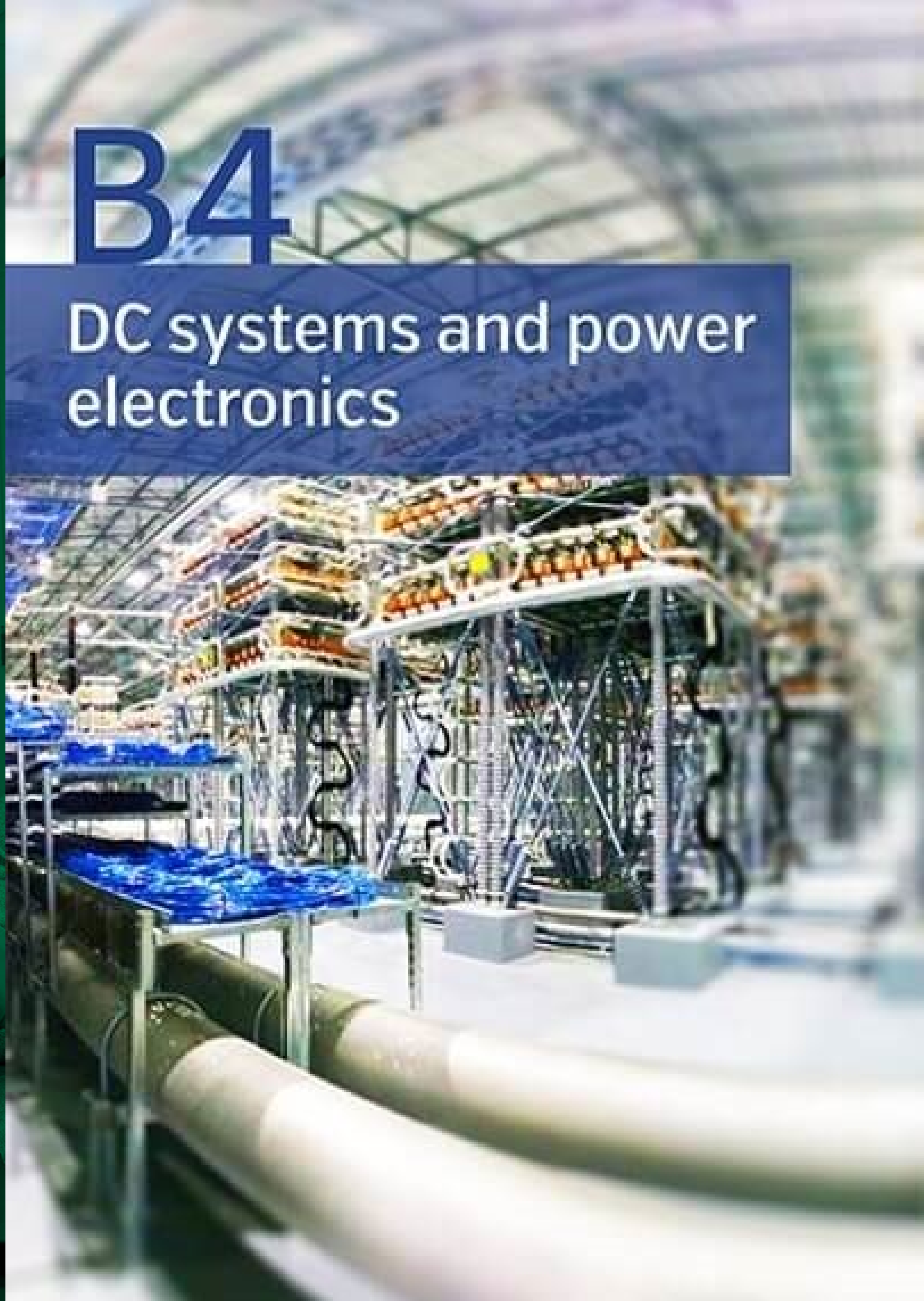

Scope of SC B4

- The scope of SC B4 covers:
  - High Voltage Direct Current (HVDC) systems and power electronic equipment for AC systems (e.g. FACTS).
  - DC systems and equipment and Power Electronics for other applications such as distribution, and Power Quality improvement.
  - DC converters for energy storage.
- Overhead lines or cables, which may be used in DC systems are not included in the scope of SC B4.
- The members of SC B4 come from manufacturers, utilities, transmission system operators (TSOs), distribution system operators (DSOs), consultants and research institutes.
- SC B4 is expanding its activities to cover DC and power electronics applications in distribution systems.

Source: Siemens

HVDC

Source: GE

FACTS

Source: ABB

DC CONVERTERS

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Scope of SC B4 – Australian and New Zealand Context

- Considering the scope of SC B4 in the Australian and New Zealand context:
  - We have been an early adopter of both major HVDC technologies (LCC and VSC):
    - Inter-Island HVDC in NZ – one of the earliest HVDC schemes in service (1965)
    - Directlink HVDC in NSW – the second VSC commissioned in the world.
    - Murraylink HVDC in Victoria/SA – at the time, and until recently, the longest underground cable in the world.
    - Basslink in Victoria/Tasmania – at the time, the longest submarine cable in the world.
  - Australia has been using FACTS devices on our transmission and distribution networks for a very long time:
    - At last count – 65 SVCs/STATCOMs on transmission and distribution system across Australia and NZ.
    - In service since 1977.
  - Recent drive for the connection of inverter connected renewable energy sources (e.g. solar) and storage solutions (e.g. batteries).
    - Australia is starting to experience (and solve!) issues that the networks in other countries have yet to experience!

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SC B4 Technical Direction

- Main changes in technical direction observed within the last 10 years, from 2009 up to 2019 are as follows:

  1. More application of VSC HVDC
  2. More feasibility and development on HVDC grids
  3. More PE applications in other areas with joint effort with other SCs
  4. Application of DC technologies started to extend to distribution
  5. Fewer LCC HVDC WGs
  6. Fewer FACTS WGs

- Industry drivers include:
  - Offshore renewable energy sources and the creation of renewable energy hubs a long distance away from the load (HVDC grids)
  - Use of PE solutions in renewable energy generation and battery storage.
  - Distribution applications driven by a balance between centralised renewable energy generation and dispersed loads.

Source: Siemens

Source: www.tdworld.com

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SC B4 Activities

- Working Groups:
  - 14 SC B4 working groups plus 5 jointing working groups.
  - Many on relatively new topics including MVDC, cyber security and EMT modelling.
  - Some examples of working groups underway include:
    - B4.64 - Impact of AC System Characteristics on the Performance of HVDC schemes
    - B4.70 - Guide for Electromagnetic Transient Studies involving VSC converters
    - B4.78 - Cyber Asset Management for HVDC/FACTS Systems
    - C6/B4.37 - Medium Voltage DC distribution systems
    - B4/A3.80 - HVDC Circuit Breakers - Technical Requirements, Stresses and Testing Methods
    - B4.81 - Interaction between nearby VSC-HVDC converters, FACTs devices, HV power electronic devices and conventional AC equipment
    - B4 .82 - Guidelines for Use of Real-Code in EMT Models for HVDC, FACTS and Inverter based generators in Power Systems Analysis

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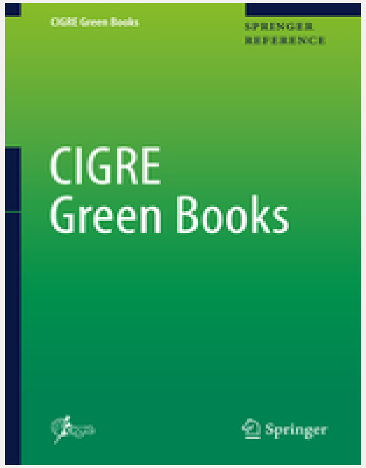
SC B4 Activities

- Recently published Technical Brochures and Articles:
  - TB 766 - Network Modelling for Harmonic Studies.
  - TB 754 - AC side harmonics and appropriate harmonic limits for VSC HVDC.
  - Paper - AC Fault response options for VSC HVDC Converters.
- Green Books
  - Green book on FACTS – to be published prior to Paris 2020.
  - Green Book on Electricity Supply of the Future – Chapter on HVDC and FACTS – to be published prior to Paris 2020.
- Working Groups About to Start
  - Use of partially open-source software for HVDC systems.
  - Commissioning of FACTS.
  - AC fault response options for VSC HVDC converters (follow on from TF 77).
- HVDC Compendium
  - An online compendium of all in-service HVDC systems around the world.
  - Being updated and revised – due April 2020.
  - Available on e-cigre.



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2019 AU/NZ Contributions to SC B4

- One paper accepted for Paris 2020:
  - “Experience of integrating FACTS based modular power flow control equipment into the Australian transmission network” by P. Harrington.
- Significant contribution by Australian and New Zealand members to the Green Book on FACTS:
  - Babak Badrzadeh
  - Peeter Muttik
  - Rizah Memisevic
  - Andrew Van Eyk
- Contributing author to Green Book on Electricity Supply of the Future, HVDC chapter (Les Brand)
- Member, SC B4 AG-01 “Advisory Group” (Les Brand).
- VSC HVDC Common Terms Document
  - Develop a “*Common Terms and Description*” document for VSC HVDC technology (Les Brand).
- Participation on International Working Groups and Task Forces:
  - Task Force TF B4.77 – “*AC Fault response options for VSC HVDC Converters*” (Simon Bartlett).
  - JWG C6/B4.37 – “*Medium Voltage DC distribution systems*” (Les Brand and Georgios Konstantinou).
  - B4 .82 – “*Guidelines for Use of Real-Code in EMT Models for HVDC, FACTS and Inverter based generators in Power Systems Analysis*” (Nathan Crook).
  - B4.78 – “*Cyber Asset Management for HVDC/FACTS Systems*” (Mark Shilliday).
- Special Reporter for Paris 2020 technical session (Les Brand).

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2019 SC B4 Colloqium

- Johannesburg, South Africa.
  - Combined with the 9th CIGRE Southern Africa Regional Conference.
  - Working Groups – 28 and 29 September 2019.
  - B4 Study Committee Meeting – 30 September 2019.
  - Tutorials – 1 October 2019 – Two tutorials presented by SC B4:
    - FACTS Planning, Technology Selection and Specification
    - Technology Selection and Specification of HVDC
  - Colloquium – 2 October to 3 October 2019
    - Three parallel streams – two covering the Southern Africa Regional Conference and one for SC B4.
    - 28 Papers presented for SC B4 covering the following topics:
      - Network Stability
      - Renewable Energy
      - LVDC and MVDC distribution and microgrids, Distributed FACTS devices, Synthetic inertia, HVDC Insulation
      - HVDC Reliability, Refurbishment and upgrades of HVDC and FACTS installations
      - HVDC and FACTS Equipment and Technology
  - Australian member chaired the session on Renewable Energy.

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2019 AU B4 Panel Meeting and Membership List

- 2019 Panel Meeting held at Queenstown, New Zealand – 12 to 14 November 2019.
- 13 out of 19 members in attendance.
- Hosted by Transpower.
- One and half days of meeting in Queenstown plus half day site visit to Benmore HVDC converter station.
- New Convenor from 2020 – Mr John Wright-Smith of AMSC.

Name	Organisation	Name	Organisation
Les Brand (Convenor)	Amplitude Consultants	**Gerard Ledwich**	Queensland University of Technology
David Gibbs	Powerlink Queensland	**Angelo Iacono**	Siemens
Luke Roberts	TasNetworks	**Michael Dalzell**	Transpower, New Zealand
Peeter Muttik	GE	**Stuart Dodds**	APA Group
Andrew van Eyk	ElectraNet	**Ranjith Perera**	Entura
John Wright-Smith	American Superconductor	**Yau Chow**	Western Power
Richard Xu	TransGrid	**Georgios Konstantinou**	University of NSW
Greg Mather	Basslink Pty Ltd	**Mark Shilliday**	AEMO
Colin Wood	ABB	**Stephen Bex**	Jacobs
Nalin Pahalawaththa	GHD		

GLOBAL TRENDS IN HVDC

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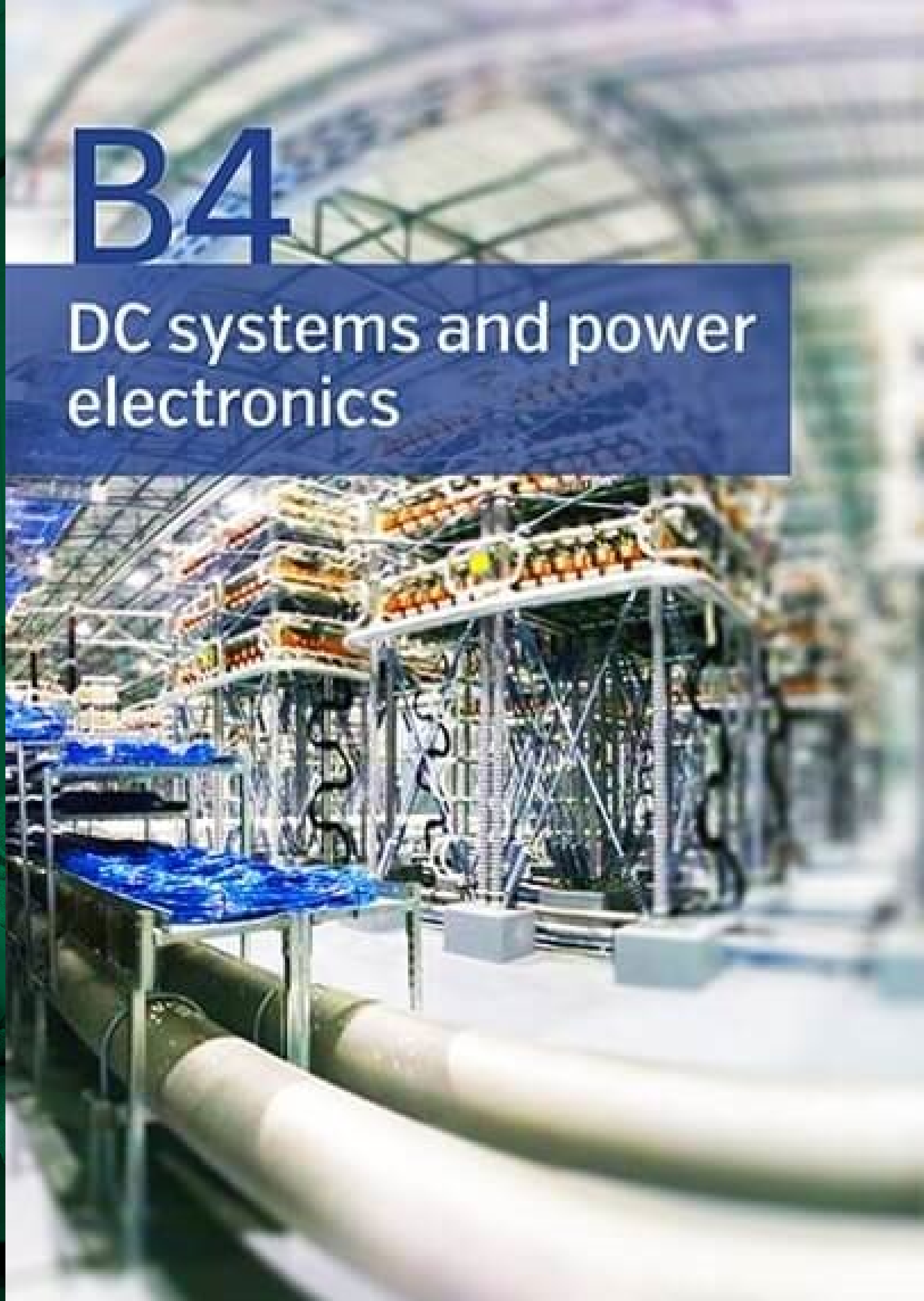

Global Trends in HVDC

- So…what's new?
- A few of my thoughts:
  - Increased application of Voltage Source Converter (VSC) projects…
  - ….but Line Commutated Converter (LCC) projects are not dead yet…just BIGGER
  - "Hybrid" HVDC Links
  - Earth return? What about "deep well" electrodes?
  - Global interconnections – the new buzz…

Source: Siemens

Source: CSPG "Ongoing HVDC Project Introduction"

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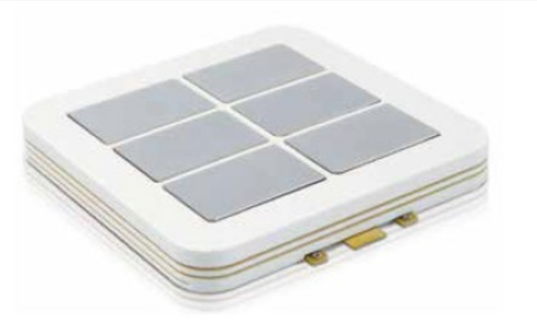
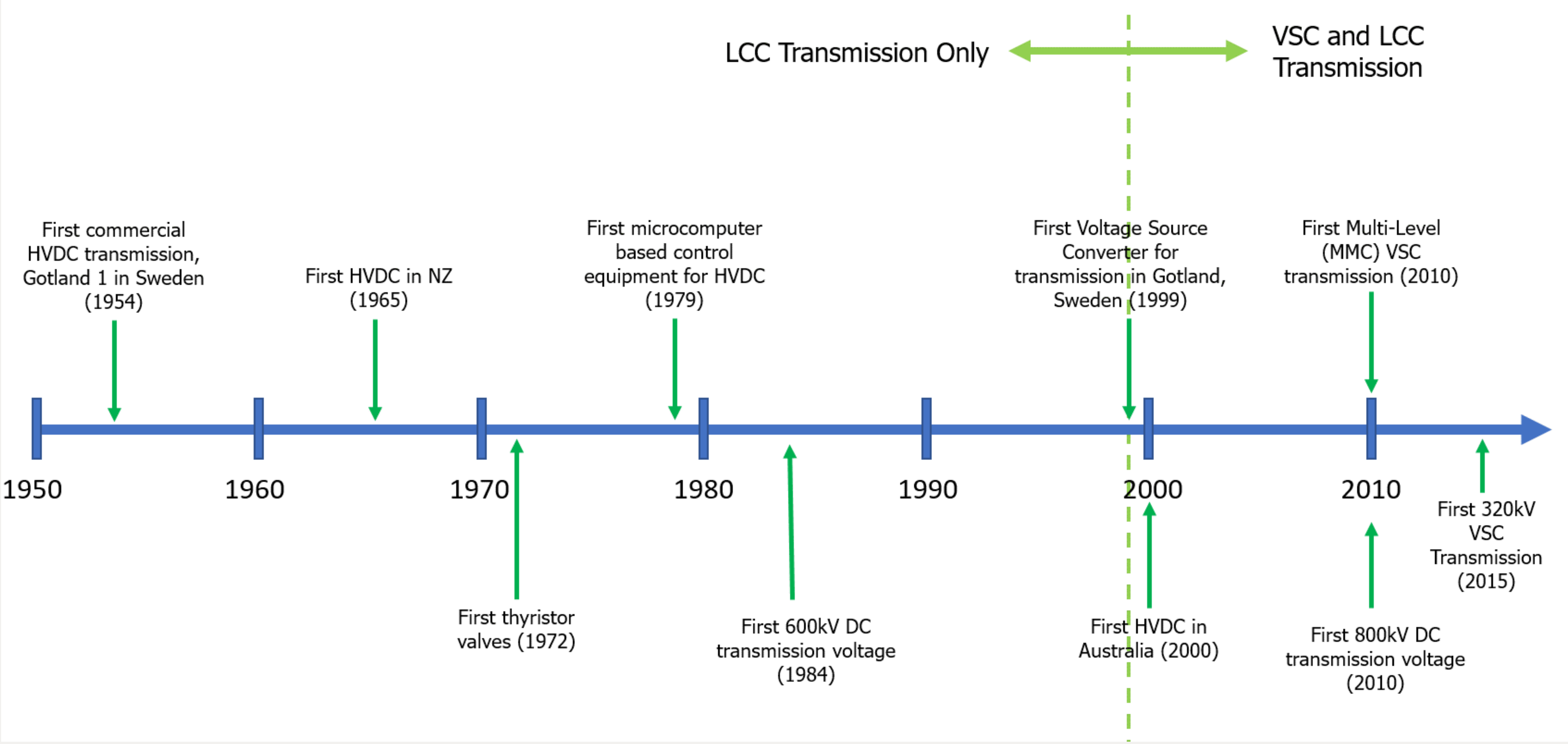
HVDC Technologies

- Line Commutated Converters (LCC)
  - ✓ Often referred to as “conventional” HVDC or “classic” HVDC.
  - ✓ Utilises thyristor valves to commutate the current.
  - ✓ Been around since the mid-1950s.
  - ✓ Thyristors in use in LCC converter stations since 1972 (prior to that mercury arc valves were used).

- Voltage Source Converters (VSC)
  - ✓ Conversion through the use of Insulated Gate Bipolar Transistors (IGBTs)
  - ✓ Self commutating - the IGBTs are switched on and off under the direction of a control system to develop an AC and DC voltage waveform.
  - ✓ HV VSC technology was first introduced commercially in 1997.



History and Development of HVDC



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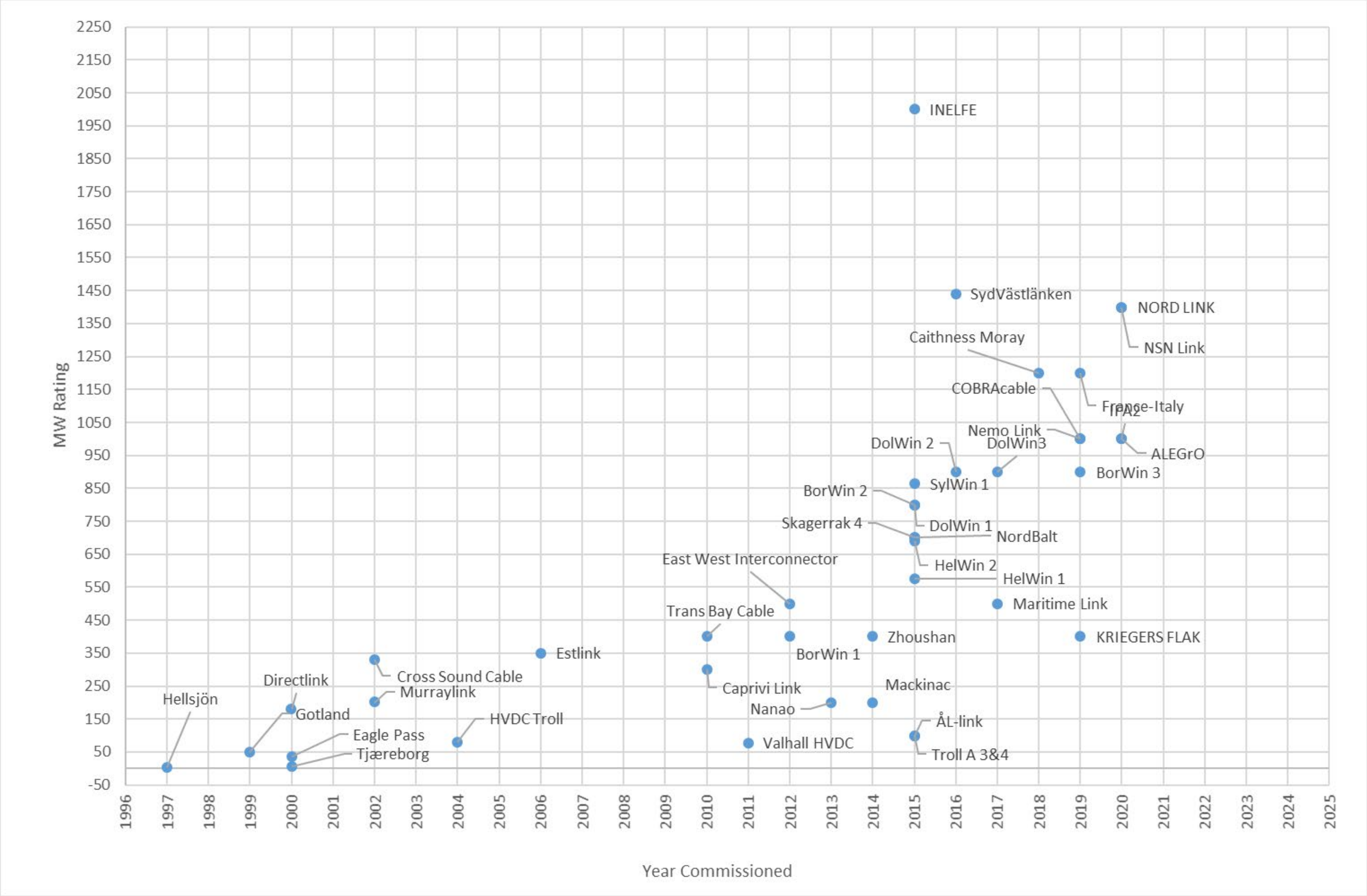
Evolution of VSC HVDC Technology



Drivers for Preference of VSC Technology

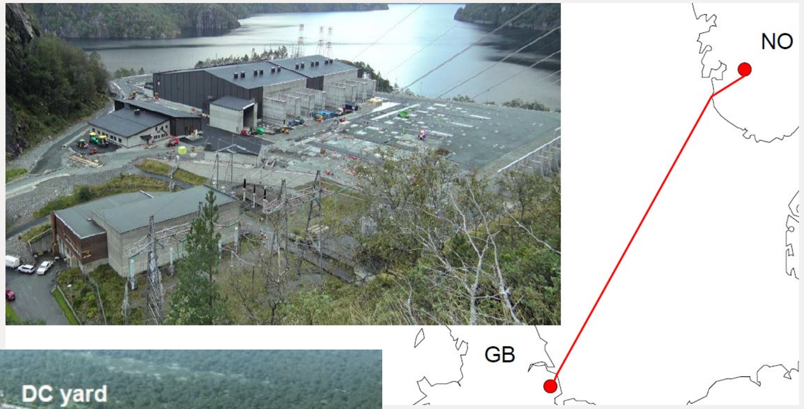
- To name a few:
  - Low power applications e.g. smaller islands, remote sites.
  - Offshore loads, some distance from shore – e.g. oil platforms.
  - Offshore generation – e.g. offshore wind – e.g. Germany off shore wind farms – up to 800MW.
  - Interconnection into / between weak networks.
  - Small footprint applications – into cities and heavily populated areas – e.g. trans bay cable.

Source: ABB

Source: Siemens

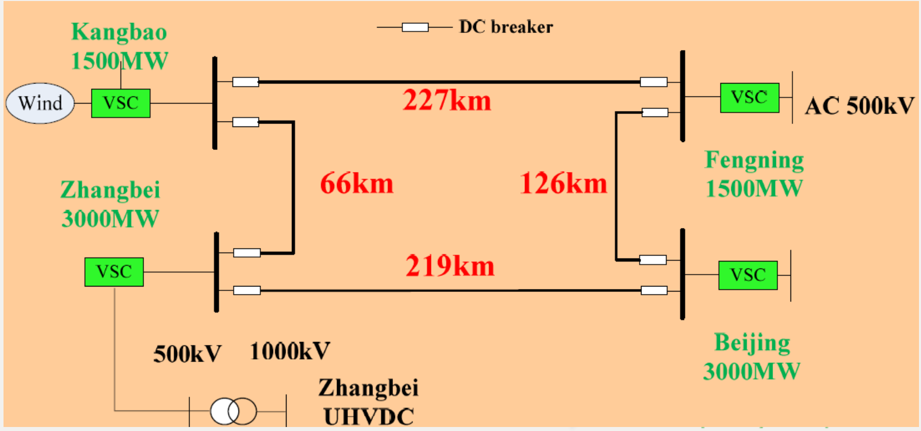
Big VSC Projects Coming Up

- North Sea Link
  - 1,400MW ±515kV
  - VSC "Rigid" Bipole
  - 720km HVDC submarine cables
  - To be commissioned 2021
- China VSC Projects
  - 5GW VSC Station – Guangdong
    - To be commissioned 2020
  - Zhangbei 4 Terminal VSC Link
    - To be commissioned 2019-2021
    - Up to 3GW converters



Source: Stattnett

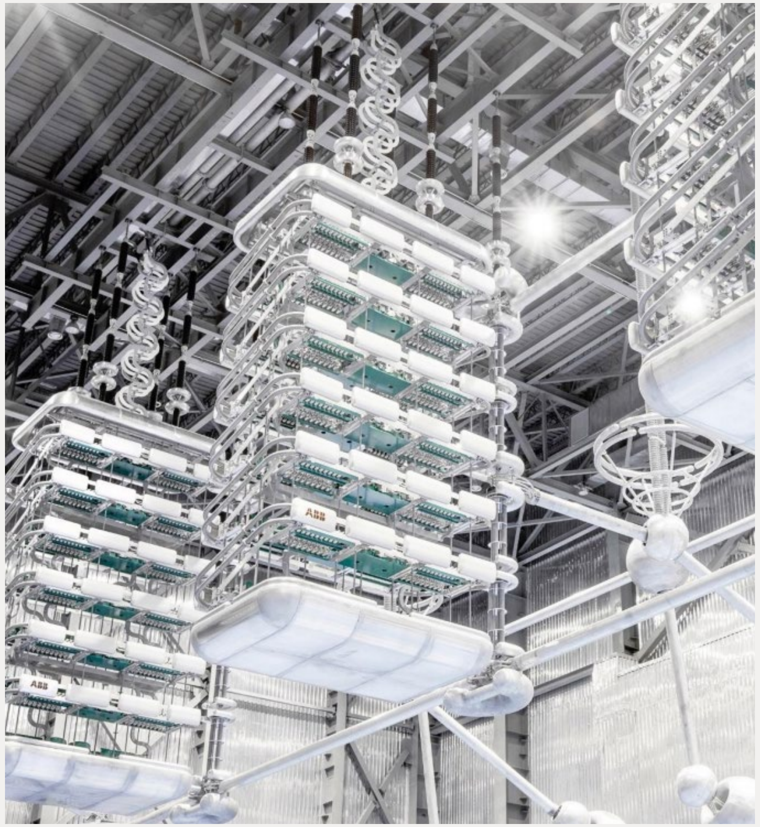
Source: China Southern Power Grid



Source: Global Energy Interconnection Research Institute China

New BIG LCC Links

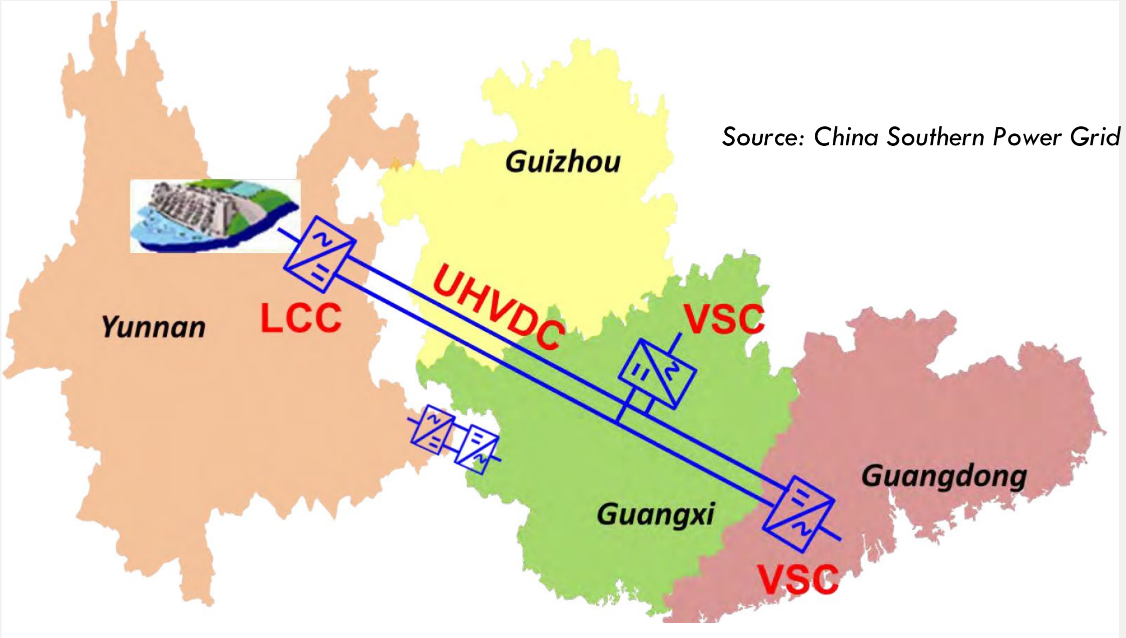
- Line Commutated Converter (LCC) technology still used for large power – long distance applications.
- Changji-Guquan UHVDC link (China)
  - 12 GW
  - ±1,100kV
  - 3,000km overhead DC line
  - First power transmission – 2019



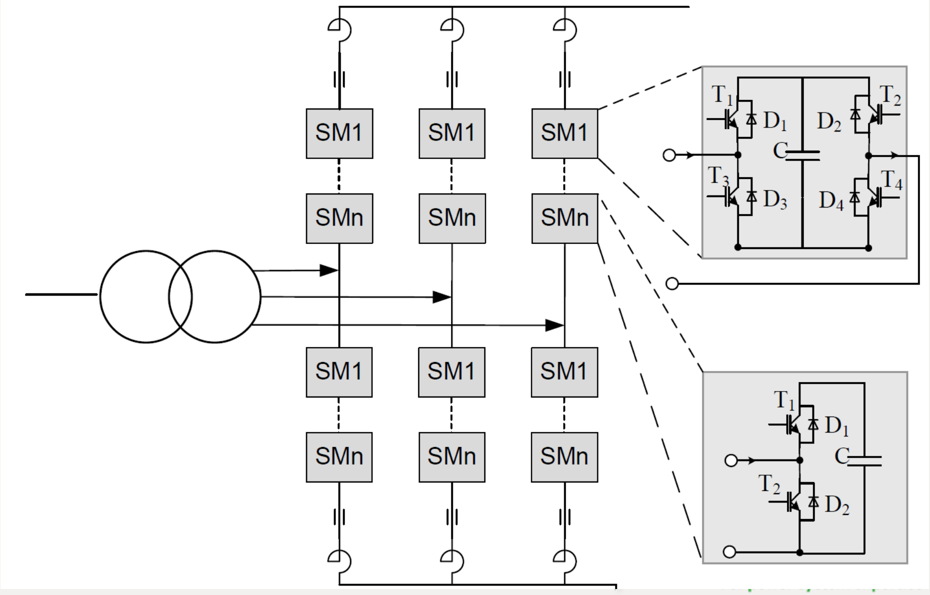
Source: ABB

“Hybrid” HVDC Links

- WDD Hybrid UHVDC Project
- Combination of LCC and VSC.
  - Rectifier – LCC – 8GW
  - Inverter 1 – VSC – 3GW
  - Inverter 2 – VSC – 5GW
- DC Voltage = ±800kV
- Why “Hybrid”?
  - Improve stability of multi-infeed system at inverter
  - No commutation failures at inverter
- Combination of half-bridge and full-bridge sub-modules:
  - Manages DC faults on overhead lines
  - Minimise costs – full-bridge = more IGBTs than half-bridge
  - Approx. 70% full-bridge.



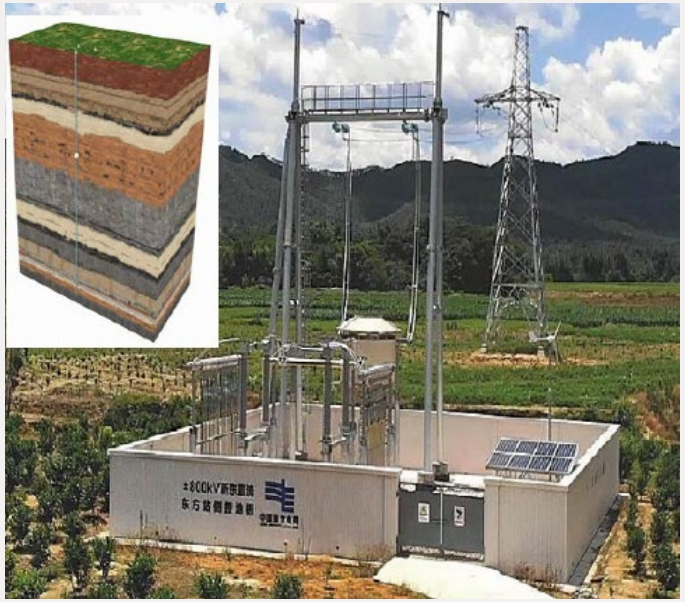
Source: China Southern Power Grid

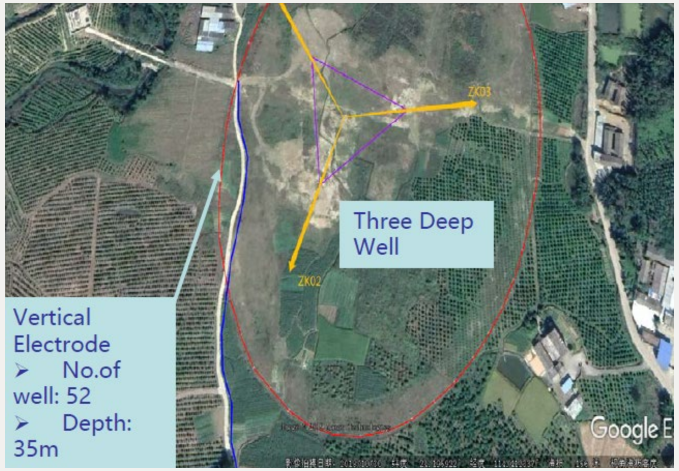


Source: China Southern Power Grid

Deep Well Electrodes

- “Conventional” earth electrodes can have impacts on the environment surrounding the electrode or other utilities and infrastructure in the vicinity.
- Project by China Southern Power Grid
  - The world's first 1000m deep-well grounding electrode project.
  - Mitigates the impact of HVDC earthing currents to the surrounding environment and other utilities.
  - Can reduce nearly two-third of the construction area of conventional earth electrode.





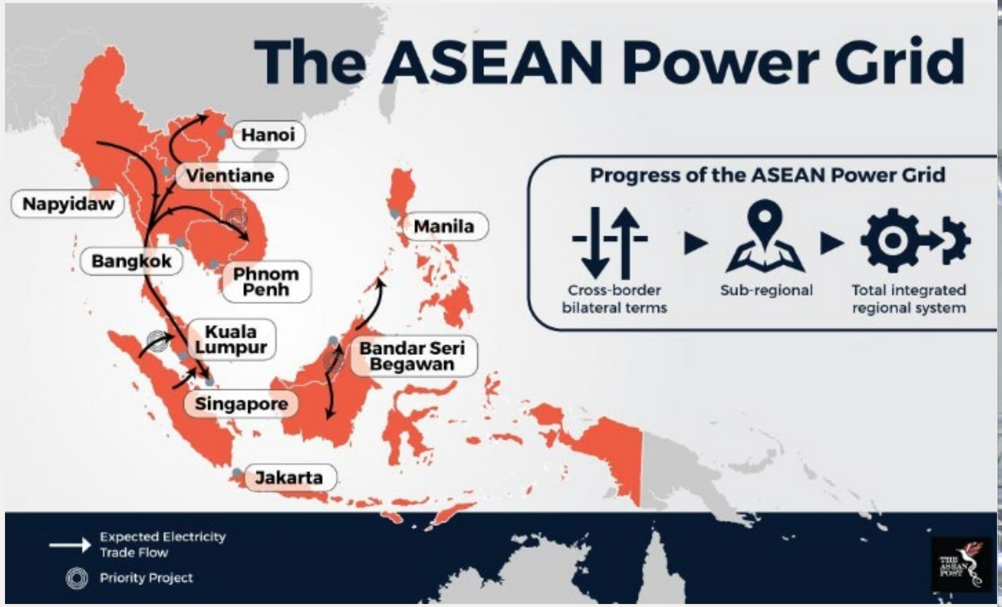
Parameters

- ➢ **Number of electrode: 3;**
- ➢ **Separation distance: 100m;**
- ➢ **Depth of single well： 1000m;**
- ➢ **End hole caliber: 406mm;**
- ➢ **Diameter of protection casing: 340mm;**
- ➢ **Upper end under ground： 150m;**
- ➢ **Diameter of feeder bar: 73mm;**

Source: Presentation by China South Power Grid, CIGRE B4 Colloquium, Johannesburg 2019

Global Interconnections

- Focus of CIGRE on global interconnectors.
- Utilising power sources in one country (e.g. renewable energy sources) to provide supply to neighbouring countries.
- Potential to take advantage of time zone differences in terms of generating capacity (e.g. daylight hours) and peak loads.
- Allow countries with minimal renewable resources (e.g. land constraints for solar) to be able to achieve renewable energy targets.
- HVDC will have a significant role in the development of such global interconnections.
- CIGRE plan to host a workshop during 2020 supported by a number of SCs, including B4.
- Some examples:
  - ASEAN Power Grid
  - North East Asia (NEA) Power System Interconnection



Source: ASEAN Centre for Energy (ACE)

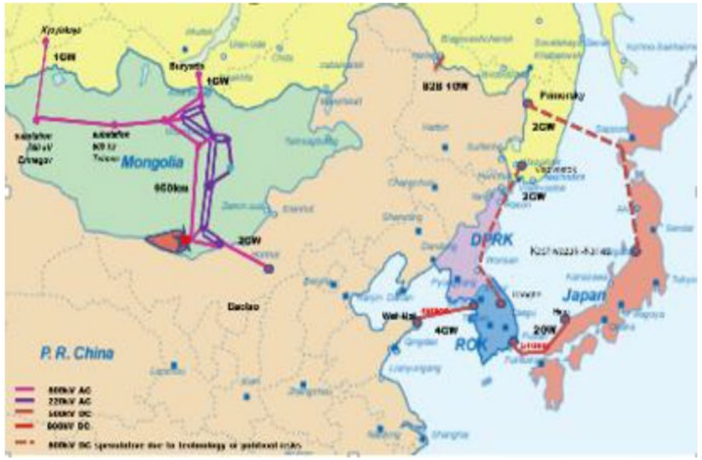
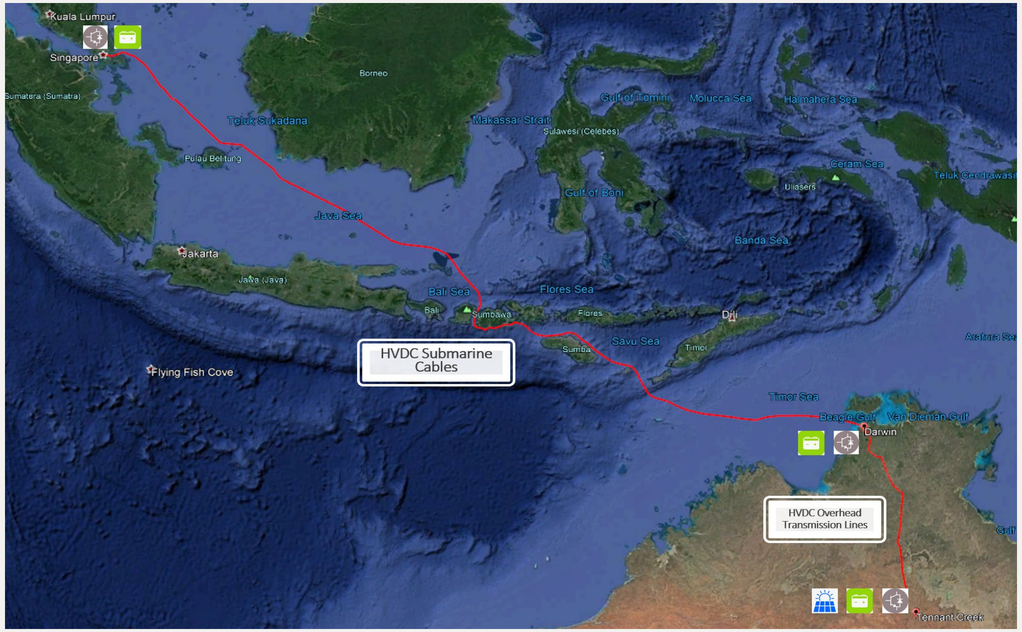


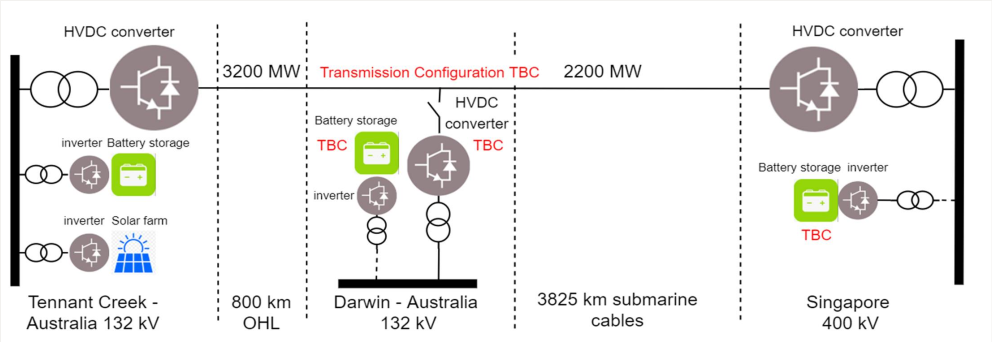
Figure 4: 5GW Renewable exportation from Mongolia by 2026

Source: EDF Electricité de France

Global Interconnections – Australian Example

- Australia-Singapore Power Link
  - A 10 GW capacity solar farm with battery storage near Tennant Creek, Northern Territory, Australia.
  - A 3,200 MW HVDC overhead transmission line system from Tennant Creek to Darwin.
  - A connection to the Darwin grid and local loads, via an HVDC converter terminal “tap”
  - A 2,200 MW HVDC subsea cable system with connection to Singapore’s transmission grid.
  - The project will be capable of producing up to 20% of Singapore’s annual electricity demand.
  - VSC technology, multi-terminal.





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Thank You For Your Time!

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