SC B4 – Key Takeaways

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Key Takeaways - Outline

- ❑ Overview (statistical) of SC B4 Papers
- ❑ SC B4 Workshop - Interoperable Multi-Terminal HVDC Systems
  From Dream to Reality
- ❑ New HVDC Projects: Which Technology LCC Vs VSC HVDC
- ❑ (End of life) Operational Projects: Refurbish (existing technology) Vs Upgrade to new technology
- ❑ Interaction between HVDC systems in the same synchronous area
  - ➢ More and more HVDC in the system means high chance for control interactions
- ❑ Grid Forming – hot-topic of SC B4
- ❑ SC B4 meeting
  - ➢ Brief updates
  - ➢ Future events

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Overview of SC B4 papers and contribution

- Three Preferential subjects
  1. DC Equipment and Systems
  2. FACTS and Power Electronics
  3. New Technologies and Concepts
  - Planning, design, performance, testing and commissioning
- Nearly 100 papers have been received, reviewed to improve quality and accepted
  - Includes 5 NGN contribution
  - 97 posters are prepared
- Nearly 100 prepared contributions submitted
  - 60 have been accepted due to time limitation
  - Several spontaneous contributions

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Preferential Subjects

- PS1: DC Equipment and Systems (**53 papers**)
  - PS1.1: DC equipment (**26 papers**)
    - PS1.1-1: LCC & Hybrid HVDC (**8 papers**)
    - PS1.1-2: VSC HVDC (**11 papers**)
    - PS1.1-3: Offshore HVDC (**7 papers**)
    - PS1.1-4: Multi-Terminal & DC Grids (**10 papers**)
  - PS1 1-2: Refurbishment and upgrade of existing DC systems (**7 papers**)
  - PS1.3: Service and operating experience (**10 papers**)
- PS2: FACTS and Power Electronics
  - PS2.1: FACTS and other PE devices including inverter-based generation (**11 papers**)
    - PS2.1-2: STATCOM & SVC (**3 papers**)
    - PS2.1-2: Power Electronic Devices and Other FACTS Devices (**8 papers**)

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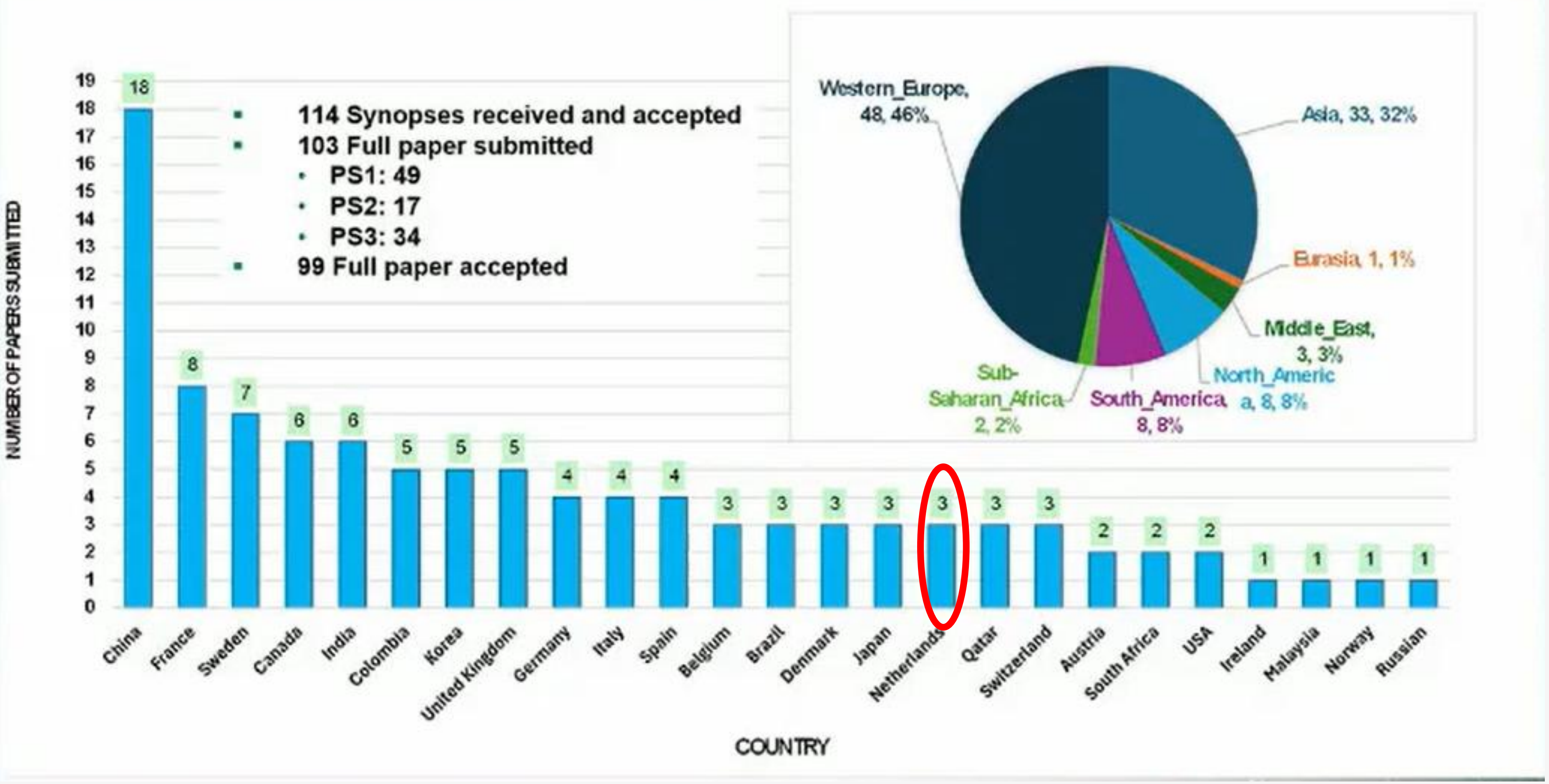
Preferential Subjects…

- PS2: FACTS and Power Electronics …
  - PS2.2: Refurbishment and upgrade of existing FACTS and other PE devices (**3 papers**)
  - PS2.3: Service and operating experience (**3 papers**)

- PS3 New Technologies and Concepts - Enabling Energy Transition
  - PS3.1: Grid-forming converters, multi-vendor interoperability (**21 papers**)
    - PS3.1-1: Modeling & Analysis for new technologies/concepts (**13 papers**)
    - PS3.1-2: Network Integration & Application of new technologies (**9 papers**)
  - PS3.2: New Concepts, Technologies and design of DC converters and PE devices - including interfacing of generation and storage to the network, energy hubs/islands, etc. (**11 papers**)

2024 SC B4 Paper Distribution



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B4 Workshop: Interoperable Multi-Terminal HVDC Systems From Dream to Reality

- ❑ 4 German TSO Innovation partnership
- ❑ InterOpera project – Focus on Multi-Vendor Inter-Operability
- ❑ Project Aquila - Similar to InterOpera but UK based (National HVDC Centre Scotland)
  - ➢ Interoperability, DCSS, procurement, regulatory and commercial aspect
- ❑ North American Perspective – with focus on the need for standardization
- ❑ Experience in China → Multi-vendor projects →Zhoushan, Zhangbei
  - ➢ Standardization and verification are key challenges
- ❑ Standardization aspects
- ❑ Focus on the need for developing common Language between different stakeholders
  - ➢ Defined architecture and interfaces
  - ➢ Defined functions along with parameters
- ❑ Vendor insights, modular development

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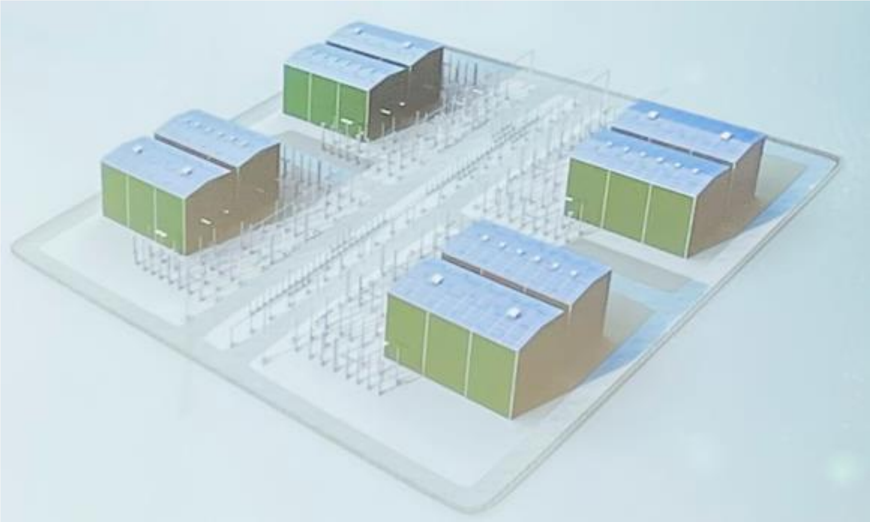
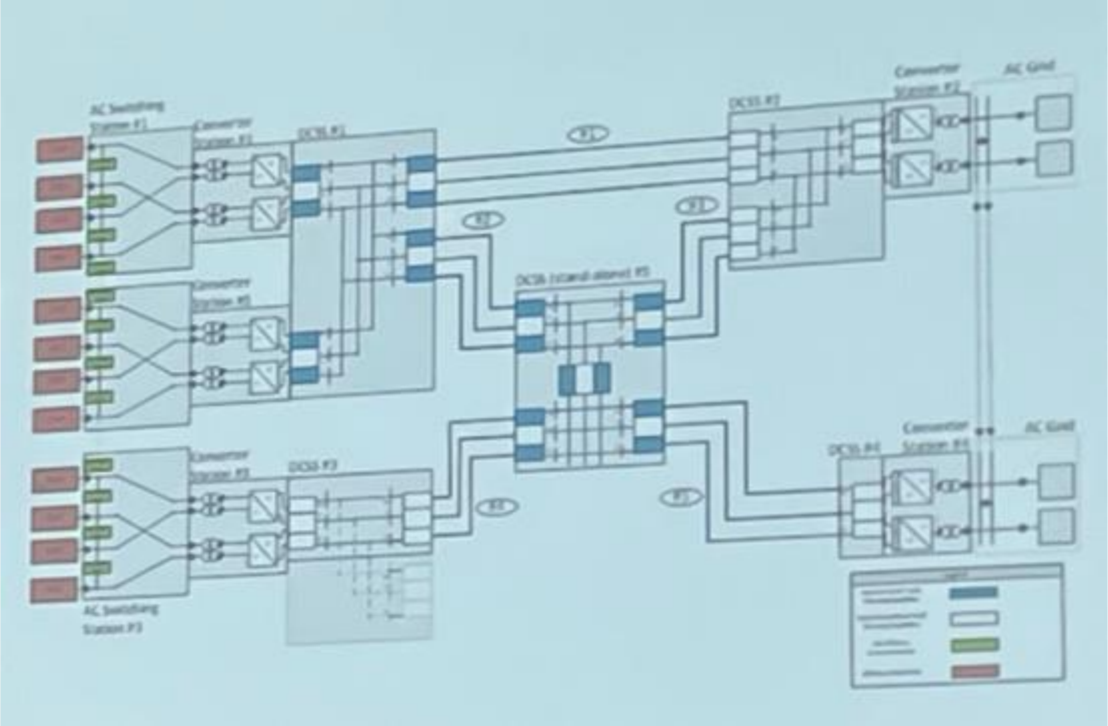
Innovation Partnership – R&D

- 4 German TSOs involved: 50 Hz, Amprion, TenneT, and TransnetBW
- Vendors
  - Hitachi energy
  - Siemens Energy (with Mitsubishi)
  - GE Grid Solutions (with Supergrid Institute)
- Development of single-vendor Multi-terminal DC with DC Circuit Breakers
  - 525 kV bipole with metallic return
  - 2 GW power per converter station
- Three DC hubs identified
  - HeideHub
  - NordWest hub
  - NordHub



InterOpera Project

- Functional Requirements of Grid Forming – in Multi-terminal Multi-vendor environment: aimed at
  - Common understanding of what GFM
  - What are GFM capabilities
  - Common validation procedures
- Demonstrator
  - 525 kV, Bipole with DMR, 2 GW power
  - With DC-FSD, stand-alone DC switching station
  - Two synchronous areas
  - Multiple operation modes (rigid bipole, asymmetric monopole, bipole with DMR)



HVDC Technology for future projects: LCC Vs VSC HVDC

- For which applications is LCC still relevant?
- What are the advantages of LCC or Improved LCC?
- Today VSC HVDC → Power rating between 3 – 5 GW or more can be achieved
  - Losses comparable to LCC
  - Power transfer capability comparable to LCC
  - Several ancillary services
- TSOs in different parts of the world contributed their experience
  - Some considering replacing LCC by MMC VSC during refurbishment (Brazilian TSO, Manitoba hydro in Canada)
  - In China improved LCC – Controllable LCC (CLCC) is introduced
- Suppliers recommend VSC

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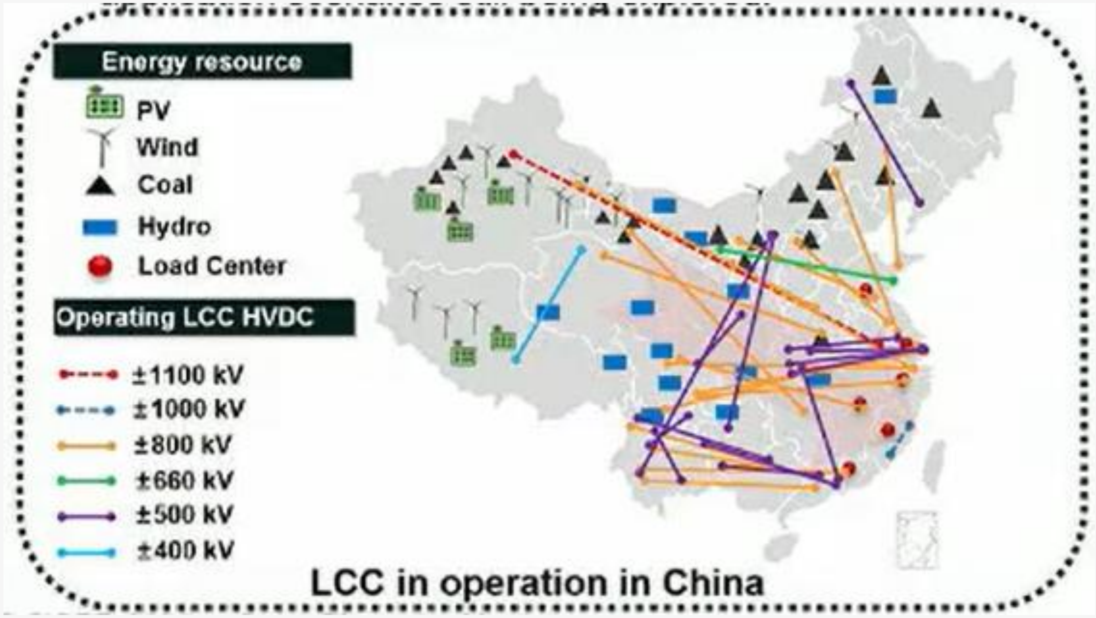
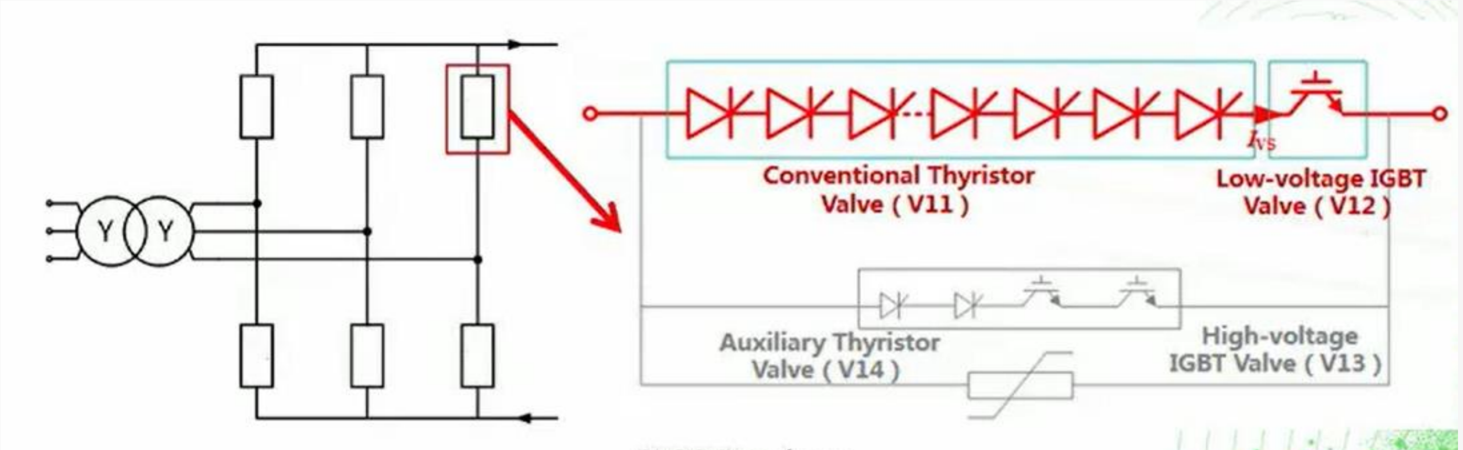
Chinese Experience

- ❑ LCC in new projects – for bulk power transmission, point-to-point, string grids and cost-sensitive scenarios
  - ➢5 new LCC HVDC systems have been commissioned at ±800 kV since 2019
- ❑ MMC VSC for weak grids and HVDC Grids – high cost, lower overload capacity compared to LCC
- ❑ New HVDC Technologies – IGCT based LCC → immune to commutation failure
  - ➢Can refurbish existing LCC on 1:1 bases in terms of volume



Refurbishment/upgrade – LCC to CLCC



CLCC Topology

Supplier Perspective

- VSC HVDC can cope-up with changing AC grid compared to LCC
  - Independent control of reactive and active power capability
  - Operation within weak networks and integration of renewables
  - Ancillary services e.g., system restoration – black start capability
  - Low harmonics generation – limited (no) need for filters
  - Grid forming capability
  - Expansion to multi-terminal DC grid
  - Grid code compliance can only be achieved by VSC MMC in many countries
  - Flexible, adaptable and scalable power rating
    - For example, 600 kV bipole systems in the design
  - Power transfer limit determined by AC network stability – single largest contingency

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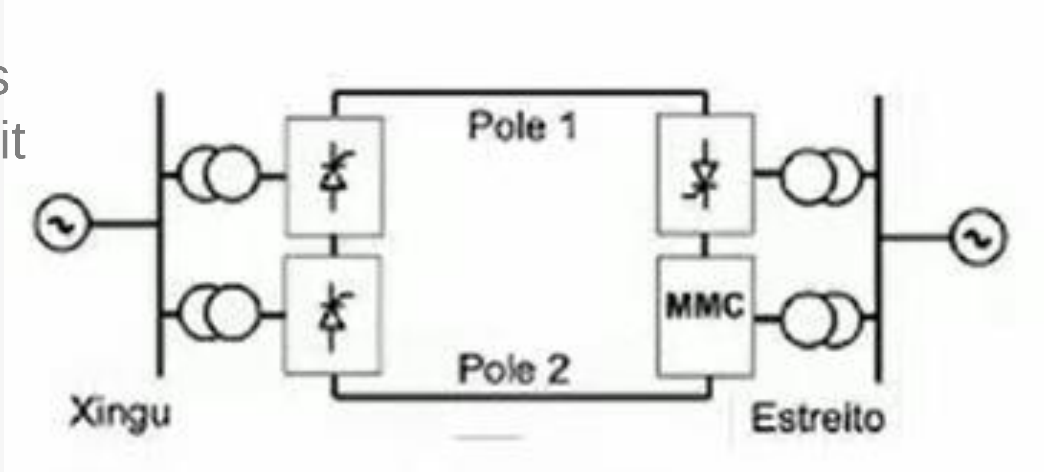
Refurbish Vs Upgrade →nsight from Brazil

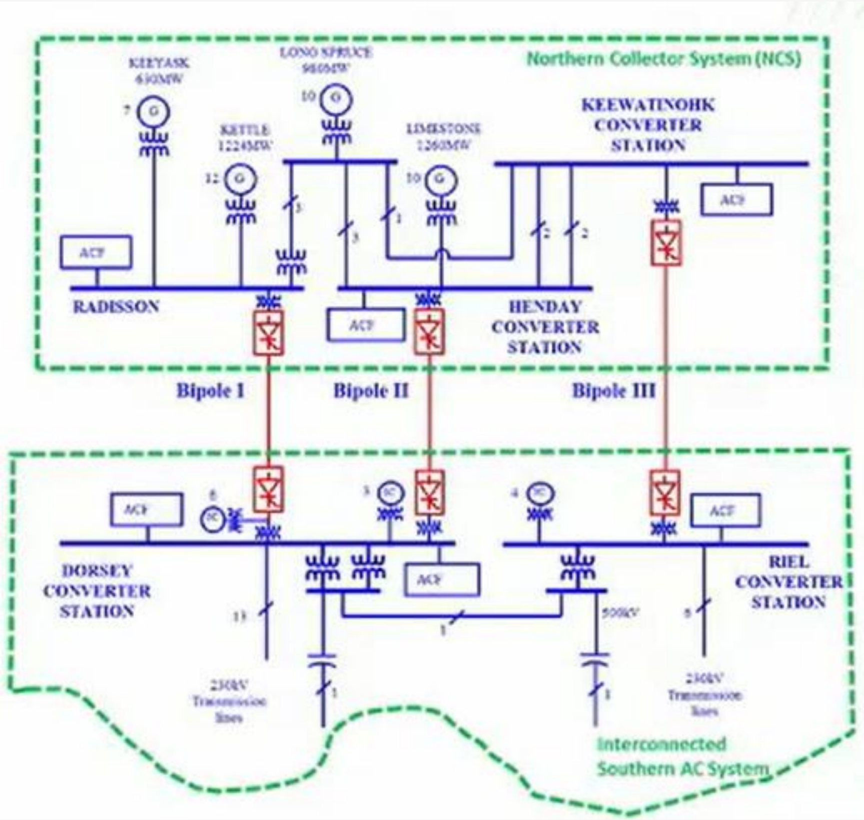
- The MMC based on full-bridge submodules which has capability of blocking short-circuit current during DC fault



- Studying what is the best – technical (recovery after fault), economical
  - One pole at a station
  - Two poles at a station or replace everything with MMC VSC
- Including VSC technology certainly improves performance

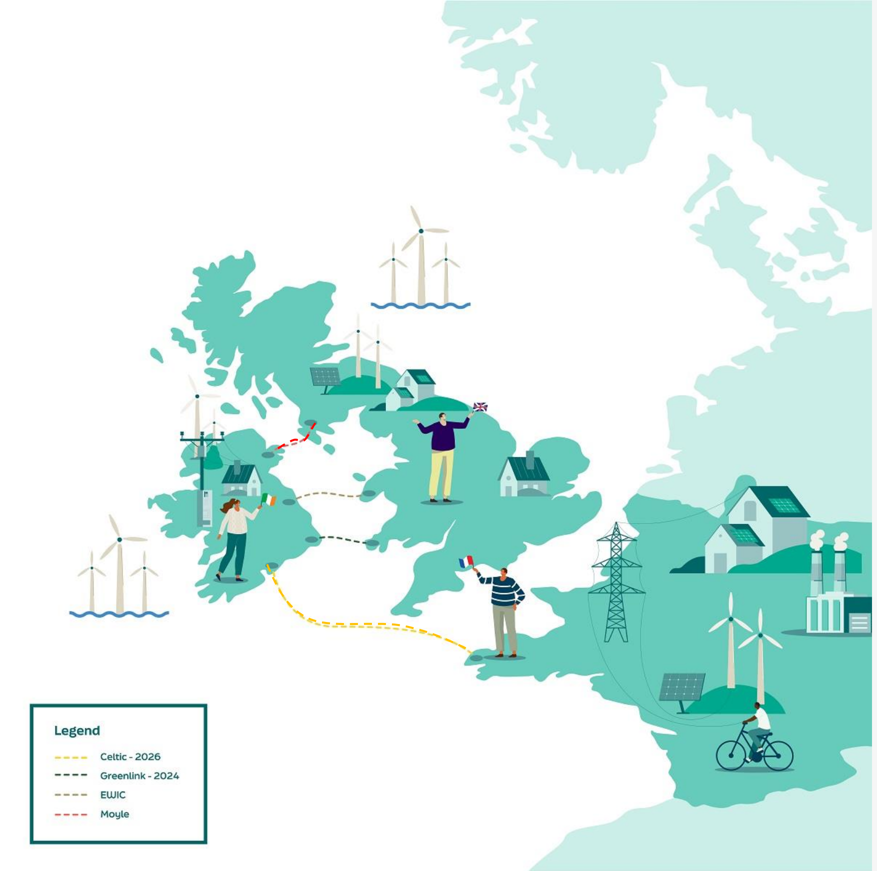
Refurbish Vs Upgrade → Canadian Insight

- ❑ Bipole I and II are reaching end of Life
- ❑ Considering replacing one of the Bipoles with VSC technology
- ❑ Replacement of VSC is feasible
  - ➢ Notable drawback is during DC line fault of the VSC
  - ➢ Due to voltage drop (<100 ms)
  - ➢ Lead to commutation failure
    - ➢ will impact system frequency
  - ➢ The chance of DC line fault is high due to considerable length



Interaction between HVDC systems → EirGrid Experience

- ❑ Experience shared by EirGrid - VSC (EWIC) fault impacting LCC (Moyle)
- ❑ 500 MW VSC HVDC tripped (Ireland ←→ Scotland)
- ❑ Sub-synchronous Torsional Interaction (SSTI) protection picked up by nearby Moyle LCC (an interconnector) (total 880 MW power lost)
- ❑ Immediate response from batteries (BESS) arrested frequency drop
  - ➢ Avoided load shedding
- ❑ Interaction between IBRs present real risk to power systems
- ❑ Additional enhanced modelling required to capture these events in study tools
- ❑ Lessons learned to be used for fine tuning of designing new technologies



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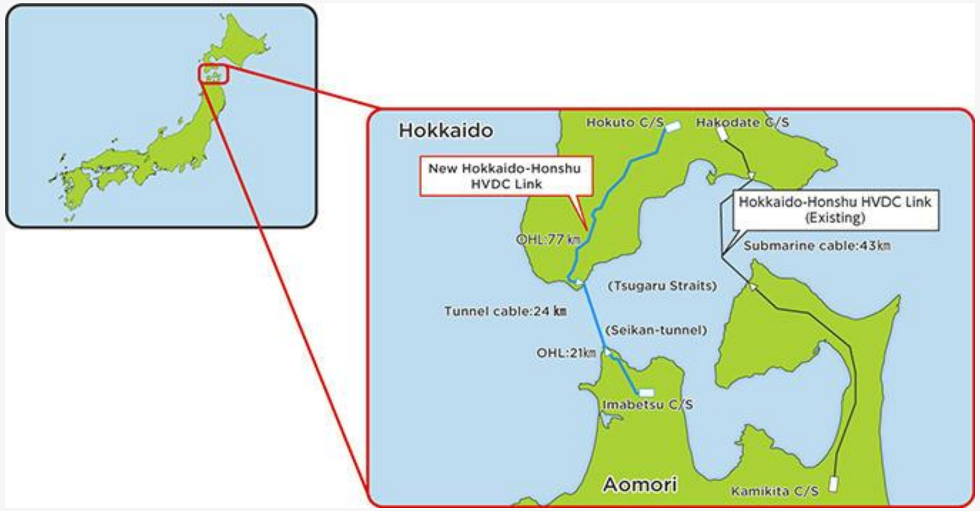
Interaction between HVDC systems → Japanese Experience

- Hokkaido-Honshu HVDC system
  - One is built in 1979 (600 MW, ±250 kV LCC, Bipolar system
  - The other is built in 2019 (300MW, 250 kV, VSC asymmetric monopole)
  - Over-voltage caused by residual reactive power at LCC (due to AC filters and Shunt capacitors) after clearing AC fault seen at VSC
    - This study is essential to determine operational limits of both HVDC systems
  - AC voltage drop caused by DC faults at VSC
    - Observed during study and confirmed that it does not cause LCC to trip



Interaction between HVDC systems → Developer Insights

- Stressed on the importance of control interaction studies
- Study scope not only limited to HVDC but also STATCOMS, Large windfarms, PVs
- Main challenges
  - Study methodology
  - Availability of reliable models
  - Scope and responsibility split between different parties

Importance of Simulation…

- Suggestion on who should build, maintain the EMT models and how often?
  - Vendor can create original model
  - After delivery of the project, the end user shall oversee updating
    - When new equipment is added, or eliminated or if operation conditions change
  - The detail of the model depends on the purpose of study

Grid Forming (GFM), Synchronous Grid Forming (SGFM)

- **Definitions** – There is no clear definition, requirement
  - GFM functionality is already there before the terminology
    - Offshore (f and v support), supporting extremely weak AC grids, black start, feeding offshore loads)
  - Capability of a converter to be able to operate in low or zero inertia rather than providing certain inertia (supplier definition)
  - Emulating synchronous generator is not a purpose of GFM, rather supporting the connected AC system with maximized performances
  - HVDC cannot provide inertia just by its control
    - Fast active power control can be counter measure for the diminished inertia
  - Main objective is to support Grid Stability by inherently counteracting the ac grid disturbances – mimicking the response of conventional synchronous generator

Grid Forming Requirements

- Flexible control of HVDC can be just one of the necessary control
  - Deploy “storable and dispatchable” resources such as BESS
  - Flexible loads/dispatchable loads, e.g., hydrogen plants, battery chargers
- Strong need to standardize GFM requirements for all technologies (HVDC, FACTS) – considering actual needs of the AC grids and capability of converters
- Clear difference between GFL and GFM objectives
  - GFL – an asset for transmission solely (HVDC)
  - GFM – an asset for grid stability enhancement (HVDC, SVC, and SVC-FS)
- Several Working Groups are involved
- Grid forming for new HVDC projects, STATCOMs with/out energy storage
- A requirement for both GFM and GFL control modes
  - Requires different converter designs and may result in suboptimal design

Grid Forming requirements…

- Transient stability, fault current injection, weak grid support, etc.
- Specific requirements determined by grid codes
- Standardize technical specification and performance requirements for GFM systems
- GFM control is supposed to emulate the characteristics of conventional synchronous generators
  - Limitation is the energy stored in the capacitors

SC B4 meeting - Updates

- New WG/TF Proposals
  - Grid Forming Capabilities and Technical Requirements of Wind Farms
    Converner: X. Zhou (UK)
    - Recommended to oversee and coordinate all GF related WGs
    - Already number of WGs on GFM → C2/B4.43, B4/C4.93 and B4.87
    - BESS that touches the same topic
- Ensure internal coordination process - review by experts already at very early stage
- Avoid negative impact on projects by defining unfeasible requirements
- Some Liaison with IEEE - There is a lot ongoing on GFM
- In C4 there is also some activity on grid forming – looking from the system perspective
  - B4 focuses on equipment like converters, inverters in wind turbines, batteries
  - On the other hand topics need to evolve, knowledge dissemination

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HVDC compendium, Green Book

- HVDC Compendium
  - List of reference projects worldwide – with all detailed information (Better than overview available in Wikipedia)
  - List of planned projects, actual projects, data (power, voltage, technology, topology, configuration, number of terminals, supplier, end user, etc.)
  - A kind of live document that is updated regularly
  - NCs are requested to provide information from
- SC B4 Greenbook
  - 54 chapters
  - 33 chapters have been published
  - 2 more in the next few weeks

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SC B4 Newsletter – Quarterly newsletter since 2022

- 8 newsletters since 2022
- Typical topics
  - Recent B4 activities and upcoming events
  - Updates on ongoing WGs
  - New Working Groups (WGs) and Task Force(s)
  - News on HVDC projects and status
  - Insights on new projects/technologies
- NewsLetter
  - New developments of power electronic based device and systems
  - B4 activities performed by Cigre national committees
  - Convener can provide a short update on their current WG
  - Latest news on HVDC projects and status
  - Any suggestions/ideas and questions on B4
- AG 03: Communications and SC B4 Website

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Upcoming Events

- Norway NC - Cigre Symposium in Trondheim, Norway
  - Call for paper is already out
  - Deadline September 12, 2024
  - May 12 -15, 2025

- Cigre 2025 Symposium in Montreal, Canada (B4/B2 Lead)
  - September 29 - October 2, 2025
  - Invitations
- Israel NC - delayed
- India NC - 2027 or 2029 symposium
- China NC -
- Call for proposals for future meetings
- New WG proposals
- Any thoughts or ideas is welcome

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Thank you for your attention!
Question?

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