CIGRE Study committe C1

PROPOSAL FOR THE CREATION OF A NEW WORKING GROUP

JWG C1/B4.58

NAME OF THE CONVENOR
Li Hui (CHINA)

TITLE
VSC-HVDC transmission system planning

THE WG APPLIES TO DISTRIBUTION NETWORKS: **NO**

ENERGY TRANSITION
5 / Grids and Flexibility

POTENTIAL BENEFIT OF WG WORK
3 / likely to contribute to new or revised industry standards
4 / state-of-the-art or innovative solutions or directions
5 / Guide or survey on techniques, or updates on past work or brochures

STRATEGIC DIRECTION
1 / The electrical power system of the future reinforcing the End-to-End nature of CIGRE: respond to speed of changes in the industry by preparing and disseminating state-ofthe-art technological advances
2 / Making the best use of the existing systems
3 / Focus of the environment and sustainability (in case the WG shows a direct contribution to at least one SDG)

SUSTAINABLE DEVELOPMENT GOAL
7 / Affordable and clean energy

BACKGROUND :
With the advancement of the "Paris Agreement", the electricity load in many regions around the world continues to grow, and clean energy industries such as wind power, photovoltaics and hydropower are developing rapidly. However, from a geographical perspective, clean energy rich areas and power load centers often exhibit an inverse distribution. For example:

- In the United Kingdom, Northern Ireland has abundant wind energy, while load centers are distributed in London and other areas of Southern England.
- In Germany, a power transfer of 1000 MW is conveyed from the offshore at Buttel coastal area with abundant wind energy, into inland load centers.
- In Brazil, clean energy sources in the Northeast need to be packaged and transmitted to core areas such as the Southeast Region, main load center with industrial areas.

On the one hand, the mismatch between power resources and load distribution is becoming a global pattern, and many countries/regions urgently need to carry out high-capacity long-distance power transmission projects to address the challenges. Compared to traditional alternating current (AC) transmission technology, high voltage direct current (HVDC) transmission technology has attracted much attention due to its advantages of long transmission distance and large transmission capacity. On the other hand, considering the limitation of short circuit current level, AC power grid is restrictedly developing, which requires more DC (direct current) transmission to reach the demand for forming power grid and mutual power supply in the future. Line-commutated converter-based high voltage direct current (LCC-HVDC) transmission technology is widely used as a conventional DC transmission technology due to its cost effectiveness. However, power systems are facing new challenges with the development of HVDC:

- Weak sending-end power system with a high proportion of renewable energy and power electronic access will cause low short-circuit ratio and transient overvoltage.

- When AC fault occurs in receiving-end with multi-infeed HVDC LCC, the voltage drop may cause the commutation failure of multiple converter stations at the same time.

Regretfully, LCC-HVDC deeply relies on AC grid to get commutation. It may cause commutation failure and even converter block in a weak AC grid. Besides, if more LCC-HVDC converters feed into the same grid, there is a risk of commutation failure of multiple LCC-HVDC converters by AC system failure, which poses a risk to its security and stability. Although LCC-HVDC has the cost advantage, there are significant problems of active power fluctuations and reactive power imbalance in the future power system. Thus, the HVDC transmission technology in certain scenarios needs more attention in system planning.

On the other hand, VSC-HVDC transmission can increase system flexibility and provide reactive power and voltage support for the grid and avoid commutation failure, because of the active-reactive power decoupling control characteristics. It has technical advantages for application in isolated islands and in meshed systems transmission, in asynchronous system interconnection (although so far more LCC projects have been realised) and in the offshore wind power transmission in coastal areas. In recent years, several VSC-HVDC demonstration projects have been put into operation or are at the stage of preliminary research worldwide, such as the continental Greece-Crete VSC-HVDC transmission project, Indonesia Sumatra-Batam VSC-HVDC transmission project, INELFE France-Spain VSC-HVDC transmission project, China-Nepal Power grid interconnection project etc., just to mention only few examples. It has to be highlighted that an emerging VSC-HVDC application has regarded “embedded HVDC links” adoption, especially in Continental Europe grid system.

Facing these new challenges, VSC-HVDC transmission technology is helpful to alleviate the transient overvoltage of DC and renewable energy nearby, which will make renewable energy and DC more coordinated in sending-end. Besides, VSC-HVDC can provide rare short-circuit current, and provide voltage support during fault recovery in receiving-end.. In recent years VSC-HVDC transmission technology has been more and more adopted, also largely replacing LCC-HVDC in some regions, and being able to be widely used in power systems; however, the influence on stability of the power system, the economic effectiveness, the operation control strategy and universal application case studies of VSC-HVDC in system planning are still not clear. This includes the application of VSC with long OHL transmission links.

Therefore, it is essential and urgent to carry out in-depth exploration on the specific scenarios of promoting the extended application of VSC-HVDC transmission technology, the flexibility of system operation and the key grid-forming technology programs of VSC-HVDC sending and receiving-end power systems connecting to the network to lay a solid foundation for the planning of VSC-HVDC transmission system.

PURPOSE / OBJECTIVE / BENEFIT OF THIS WORK :

This working group aims to propose power VSC-HVDC transmission system planning methods, considering both the sending and receiving end, based on the scenario of large volumes of renewable energy being transmitted via long-distance and large-capacity transmission lines to multi-HVDC feed-in load centers, to enable the building of future VSC-HVDC systems which are environmentally friendly, secure, stable, economic, and adaptable for future development.

SC C4: There are some technical performance items mentioned in the ToR that could fall within the SC C4 scope, but it is not clear the depth of detail that the JWG intends to cover them. I would suggest SC C4 to support the work with liaison members.
SC A3: Short-circuit ratio for multiple renewable energy stations and Transient overvoltage are two aspects which could impact components like Circuit Breakers and Surge Arresters. In particular for Surge Arresters, not only the overvoltage but also the estimation of impulse energy could require a larger energy adsorption that normally experienced. Depending on how these two aspects are going to be addressed, A3 could eventually contribute to the group.

SCOPE :

The scope of this WG is the development of criteria and methodologies for voltage-source converter-based high voltage direct current (VSC-HVDC) transmission system planning, with isolated cables and overhead lines (OHL), in different scenarios and flexibility needs with special focus on planning with innovative models, technologies and analysis methods.

The working group aims to carry out the following tasks:

To investigate HVAC, LCC-HVDC, VSC-HVDC technology (including with OHL application) and VSC-HVDC projects around the world including the upgraded technology.

To compare and analyse the transmission system, based on the perspective of power system planning.

- Project positioning
- Application scenarios
- Environmental impact
- Operation strategies
- Power quality
- Economic benefits and cost

To summarize the typical application scenarios of VSC-HVDC transmission.

According to the future development trend of the power system, propose the demand of VSC-HVDC transmission.

- Long-distance and large-capacity transmission
- Large renewable energy-based including solar power and wind power at the sending end
- Load center with multiple DC transmission lines at the receiving end

To research the VSC-HVDC planning technology at the sending end, based on the scenario of large renewable energy sending out via the long-distance and large-capacity transmission, VSC planning technology, and current and prospective grid planning, including:

- Operation strategy
- Security and stability characteristics
- Short-circuit ratio for multiple renewable energy stations
- Transient overvoltage
- Internal rate of return (IRR) and cost
- Grid-forming technology

To propose the VSC-HVDC transmission system planning method in sending end, considering the following facts:

- Security and stability
- Economic benefit
- Adaptability for future development

To research the VSC-HVDC planning technology in receiving end, based on the scenario of multi-HVDC feed-ins via the long-distance and large-capacity transmission, VSC planning technology, and current and prospective grid planning, including:

- Operation strategy
- Security and stability characteristics
- Multi-infeed short circuit ratio
- Fault characteristics and system recovery characteristics
- Reactive power support capability and voltage control capability
- GHG (greenhouse gas) emissions
- Internal rate of return (IRR) and cost
- Grid-forming technology

To propose the power VSC-HVDC transmission system planning method at the receiving end, considering the following facts:

- Environmental impact
- Security and stability
- Economic benefit
- Adaptability for future development

Remarks:

For the above topics, the existing data and cases will be investigated to analyse the key influencing factors, rationale and criteria for the selected projects. In this way, the generally applicable conclusions can be obtained as useful guidelines for the design of future projects. Innovative models, technologies and analysis methods directly relevant to VSC-HVDC will also be summarized to design reliable and resilient power systems.

Contributions from SC B4 on previous work on VSC shall be utilised as starting base, as well as from C4, regarding technical performances, through liason member.

Expert advise from SC A3 will be sought on short-circuit ratio for multiple renewable energy stations and transient overvoltage; these two aspects could impact components like Circuit Breakers and Surge Arresters, if these components will be within scope of the WG study.

DELIVERABLES AND EVENTS

Deliverables Types

Annual progress and activity report to Study Committee
Electra report
Event
Technical Brochure and Executive Summary in Electra
Tutorial
Webinar

Time schedule

Q1 2025 • Recruit members (National Committees, WiE, NGN)

Q1 2026 • Develop final work plan

Q2	2027	• Draft TB for Study Committee Review
Q3	2027	Final TB
Q4	2027	Tutorial/Webinar

APPROVAL BY TECHNICAL COUNCIL CHAIRMAN:
Rannveig S. J. Loken
December 16th, 2025