CIGRE Study Committee B4

PROPOSAL FOR THE CREATION OF A NEW WORKING GROUP

WG B4°96	**Name of Convenor: Qi Guo** (CHINA)	
Strategic Directions #[2]: 1		**Sustainable Development Goal #[3]: 7, 9, 13**
The WG applies to distribution networks: ☐ Yes / ☒ No		
Potential Benefit of WG work #[4] : 1, 2 , 3, 4		
Title of the Group: HVDC connection of power system with high proportion of photovoltaic (PV) generation		

Scope, deliverables and proposed time schedule of the Group:

Background:

As the world becomes increasingly concerned about climate change, many countries are implementing zero-carbon policies to promote the development of clean energy such as solar and wind power.

Photovoltaics, as a renewable and zero-emission clean energy source, have become the preferred choice for many countries and enterprises. According to data from the International Renewable Energy Agency report "RENEWABLE CAPACITY STATISTICS 2023", the growth rate of photovoltaic power generation has been remarkable in recent years. The global installed capacity of photovoltaic power generation has increased from 137 gigawatts in 2013 to 855 gigawatts in 2021, with an average annual growth rate of approximately 26%. In 2022, the world is expected to witness the installation of 192 gigawatts of new photovoltaic capacity, pushing the cumulative installed capacity to exceed 1,047 gigawatts, with China, the United States, and the European Union contributing significantly to the installed capacity of photovoltaic power generation. With the rapid development of photovoltaic power generation, massive photovoltaic power stations have been developed all over the world. In United States, Solar Star power plant began operating since 2015 with a capacity of 747 MW. In China, Tengger Desert Solar Park was operating since 2016 with a capacity of 1,547 MW. In United Arab Emirates, Noor Abu Dhabi solar power plant began commercial operation in 2019 with a capacity of 1,177 MW. In India, Bhadla Solar Park was commissioned in 2020 with a capacity of 2,245 MW.

VSC-HVDC has been largely used for both offshore and onshore wind power transmission due to the technical advantages it offers. The rapid development of photovoltaic power generation has paved the way for utilizing VSC-HVDC technology to transmit massive photovoltaic energy as well. However, the application of this innovative technology poses a series of challenges including the selection of the appropriate capacity and networking scheme to satisfy economic and stability requirements, accurately modeling and simulating large-scale power electronics (photovoltaic power stations), meeting the renewable transmission demands for HVDC technology, resolving technical issues such as the low inertia of renewable energy sending system, and addressing the dynamic characteristics which are dominated by converter control in electromagnetic transient processes. Additionally, due to the unique characteristics of power electronics, complex scenarios, and multiple disturbances, the risk of broadband oscillation is given a lot of attention. Improvement of HVDC and PV stability control technologies are also needed for problems such as the incompatibility of traditional power system stability control. A systematic study and resolution of these problems are necessary to promote the development of HVDC technology and large-scale photovoltaic integration.

In summary, photovoltaics, as a clean and renewable energy source, have become a vital implementation of the global energy transition. Large-scale photovoltaic energy utilizing VSC-HVDC transmission technology can effectively address the grid fluctuation and instability, presenting a vast range of application prospects. Despite the technical challenges associated with VSC-HVDC technology, sustaining technological innovation are expected to play a crucial role in the future of HVDC connection of large-scale photovoltaic power generation.

Scope:

This working group will briefly describe the difference between PV and wind power infeed in terms of HVDC connection but with focus on the technical requirements and solutions for HVDC connection of the power system with high proportion PV generation. The scope will be limited to the technical requirements on the performance of both HVDC system and the PV generation, including the follow tasks.

1. Definition and requirements for HVDC connection of high proportion of PV generation

This task will cover the definition for HVDC connection of power system with high proportion of PV generation, including:

- Definition and typical system schemes
- PV integration and networking
- HVDC capacity requirement and design

2. Simulation methodologies and application

This task will define the requirements of general system network for various types of simulation modelling and the guidelines for the simulation and studies of HVDC integration of PV generations, including:

- Typical system networks and models
- Transient Stability Analysis
- Electromagnetic Transients
- Real-Time Simulation

3. HVDC control system and energy absorbing device

This task will provide the specific HVDC control functionalities and energy absorbing device required for fault ride-through in the HVDC connection of high proportion PV generation, including:

- Design of energy absorbing device and its control
- HVDC control system and specific functionalities

4. System stability analysis

This task will investigate the system stability issues due to the very low inertia and high proportion of power electronic, including:

- Out-of-step instability caused by phase-locked-loop (PLL)
- Transient over-voltage
- AC and DC fault-ride-through and recovery
- Low-frequency oscillation

5. Broadband oscillation

This task will introduce the broadband oscillation issues of this kind of power system and provide the methods for investigation, including:

- Sub-synchronous oscillation
- Super-synchronous oscillation
- High frequency resonance

6. Control technology improvement

This task will investigate the control technologies to improve system stability performance, based on the fast response of HVDC or power electronic device (PV generation), including:

- Grid forming control technology of MMC-HVDC
- Control technology of AC and DC energy-absorbing devices
- Improved fault ride-through control of PV inverter
- Emergent control of PV generation in extreme fault conditions

☒ Annual Progress and Activity Report to Study Committee
☒ Technical Brochure and Executive Summary in Electra
☒ Electra Report
☐ Future Connections
☐ CIGRE Science & Engineering (CSE) Journal
☐ Tutorial
☒ Webinar

Time Schedule:

• Recruit members (National Committees)	Q4 2023
• Develop final work plan	Q1 2024
• Draft TB for Study Committee Review	Q3 2026
• Final TB	Q4 2026
• Webinar	Q1 2027

Time Schedule: Start : October 2023 **Final report** : October 2026

Comments from Chairmen of SCs concerned:

Approval by Technical Committee Chairman:

Date : June 22nd, 2023

Notes:
[1] Working Group (WG) or Joint WG (JWG),
[2] See attached Table 1,
[3]See attached Table 2 and CIGRE reference Paper: Sustainability – at the heart of CIGRE's work.
[4] See attached Table 3

WG Membership: refer Comments at end of document.

Table 1: Strategic directions of the Technical Council

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-of-the-art technological advances
2	Making the best use of the existing systems
3	Focus on the environment and sustainability (in case the WG shows a direct contribution to at least one SDG)
4	Preparation of material readable for non-technical audience

Table 2: Environmental requirements and sustainable development goals

	CIGRE selected the 7 SDGs that are the most relevant to CIGRE. In case the WG work refers to other SDGs or do not address any specific SDG, it will be quoted 0.
0	Other SDGs or not applied
7	**SDG 7: Affordable and clean energy** Increase share of renewable energy; e.g. expand infrastructure for supplying sustainable energy services; ensure universal access to affordable, reliable, and modern energy services; energy efficiency; facilitate access to clean energy research and technology
9	**SDG 9: Industry, innovation and infrastructure** Facilitate sustainable infrastructure development; facilitate technological and technical support
11	**SDG 11: Sustainable cities and communities** Increase attention on sustainable and resilient buildings utilizing local (raw) materials, power for electric vehicles, strengthening long-line transmission and distribution systems to import necessary power to cities, developing micro-grids to reinforce the sustainable nature of cities; protect and safeguard the world's cultural and natural heritage; reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and waste management
12	**SDG 12: Responsible consumption and production** E.g. Promote public procurement practices that are sustainable; address reducing use of SF6 and promote alternatives, encourage companies to adopt sustainable practices and to integrate sustainability information into their reporting cycle, address inefficient fossil-fuel subsidies that encourage wasteful consumption
13	**SDG 13: Climate action** E.g. Increase share of renewable or other CO_2-free energy; energy efficiency; expand infrastructure for supplying sustainable energy; strengthen resilience and adaptive capacity to climate-related hazards and natural disasters; integrate climate change measures into national policies, strategies and planning; improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning
14	**SDG 14: Life below water** E.g. Effects of offshore windfarms; effects of submarine cables on sea-life
15	**SDG 15: Life on land** E.g. Attention for vegetation management; bird collisions; integration of substations and lines into the landscape

Table 3: Potential benefit of work

1	Commercial, business, social and economic benefits for industry or the community can be identified as a direct result of this work
2	Existing or future high interest in the work from a wide range of stakeholders
3	Work is likely to contribute to new or revised industry standards or with other long term interest for the Electric Power Industry
4	State-of-the-art or innovative solutions or new technical directions
5	Guide or survey related to existing techniques; or an update on past work or previous Technical Brochures
6	Work likely to contribute to improved safety.

Comments:

1) CIGRE Official Study Committee Rules: WG Membership

a. Only one member per country (by exception of SC Chair)
b. WG nominees must first be supported by their National Committee (or local SC Member) as an appropriate representative of their country.
c. Acceptance of the nomination is granted by the SC Chair and advised to the WG Convener

2) Collaboration Space

https://www.cigre.org/article/GB/collaborative-tools-2

CIGRE will provision the WG with a dedicated Knowledge Management System Space.

The WG will use the KMS for drafting collaboration, capture and retention of discussion and meeting records.

Official country WG Members will be sent registration instructions by the Convener.

Official country WG Members may request the WG Convener to allow additional access for an extra national subject matter specialist to aid in the work at the national level, including NGN members.