CIGRE Study Committee B4

PROPOSAL FOR THE CREATION OF A NEW WORKING GROUP

WG[1] B4.102	**Name of Convenor:** Zhiyong Yuan (CHINA) **E-mail address**: yuanzy1@csg.cn
Strategic Directions #[2]: 1	**Sustainable Development Goal #[3]: 7, 9, 13**

This Working Group addresses these Energy Transition topics:

- [ ] Storage
- [ ] Hydrogen
- [ ] Digitalization
- [ ] Sustainability and Climate Change
- [x] Grids and Flexibility
- [x] Solar PV and Wind
- [ ] Consumers, Prosumers and Electrical Vehicles
- [ ] Sector Integration
- [ ] None of them

Potential Benefit of WG work #[4] : 1, 2, 3, 4

Title of the Group: Technical Requirements and Scenario Considerations on Grid-Forming Capabilities of VSC-HVDC Systems

Scope, deliverables and proposed time schedule of the Group:

Background:

Voltage sourced converter (VSC) based HVDC (VSC-HVDC) systems play a critical role in grid interconnection, long-distance transmission of renewable energy, city power supply, etc. To date, more than 40 VSC-HVDC projects are already in operation, and 50+ projects are in the planning phase. With the dc voltage level growing from 30kV to 800 kV and power capacity from 20MW to 5000 MW, VSC-HVDC converters have become a critical asset in power grids.

However, the massive integration of power-electronic converters along with the continuous displacement of synchronous generators is fundamentally changing the dynamic characteristics of legacy power systems, which imposes new challenge on the stable and resilient operation of power grids. The VSC-HVDC systems, instead of being simple passive transmission components, are expected to be more actively involved in the support of power grids. The grid-forming (GFM) technology, when it is applied to the VSC-HVDC system, is emerging as a promising solution to changing the role of the VSC-HVDC system from “relying on the grids” to “supporting the grids”.

Grid-forming control (GFM) technologies were introduced to inverters for improving frequency and voltage stability control in reduced and low inertia portions of power systems such as isolated windfarm interconnections. To investigate the requirements and performance of GFM controls, CIGRE B4 has already initiated a number of working groups (WGs) addressing several the GFM related topics associated with the VSC-HVDC systems as follows:

a) CIGRE WG B4.84, “Feasibility study and application of electric energy storage systems embedded in HVDC systems”, aims at investigating the connection of electric storage to VSC-HVDC systems.
b) CIGRE WG B4.87, “Voltage source converter (VSC) HVDC responses to disturbances and faults in AC systems which have low synchronous generation”,

reviews different types of converter controls including the GFM and identifies the requirements for each type of control in the fault responses.

c) In 2021, SC B4 decided to establish a new JWG B4/C4.93- “Development of Grid Forming Converters for Secure and Reliable Operation of Future Electricity Systems”, to review the work performed by the above WGs and to define broadened high level functions and design requirements of the GFM converters so they can be applied to a wider range of PE-based systems and devices. As the GFM technologies are evolving rapidly driven by the need to provide the reliable network operation and control, it was planned to form the new WGs to address specific aspects of GFM once they are identified by JWG B4/C4.93 during the course of their work so that we can react and address these topics in a timely fashion. Subsequently, two new WGs B4.94 and B4.101 were formed.

d) B4.94, “Application of VSC-HVDC in a system black start restoration”, will analyze the black start technology and will define the requirements for VSC-HVDC system to operate in the black start mode.

e) B4.101 will cover industrial implementation and application of grid forming energy storage systems (GFM ESS).

VSC-HVDC technologies are already being applied in different applications, e.g., the VSC-HVDC system connecting isolated large-scale renewable energy resources, the VSC-HVDC system interconnecting asynchronous AC grids, and the VSC-HVDC system used in a meshed synchronous AC grid known as the embedded HVDC system. The system topology may also transit from one scenario to another caused by power system contingencies, e.g., an embedded HVDC link may become an interconnection when the parallel AC lines are disconnected. The GFM requirements for the VSC-HVDC system will vary with various application scenarios, e.g., the inertia provision may be mandatory when the HVDC is applied in the interconnection of asynchronous ac grids, and may be unnecessary when the HVDC is connected to PV plants forming a 100% power electronic-based islanded system. Hence, it is important to present to the stakeholders a clear picture of the GFM requirements for VSC-HVDC systems in different scenarios.

The WG B4.84, B4.87, B4.94 and B4.101 focus on the implementation of one or several specific GFM functions and performance while this new WG will address the application of GFM in various network scenarios specifically, as one of the downstream GFM WGs following the topics of WG B4.93.

Purpose/Objective/Benefit of this work:

The main objective of this proposed WG aims to provide detailed **reasoning and illustration of the benefits** of GFM-based VSC-HVDC capability in **several representative application scenarios** including those in which optional GFM capability may become mandatory following an operational topology or scenario. The WG is expected to help system planners, operators and vendors to have a clearer picture of the benefits of GFM technology in VSC-HVDC systems, and a better understanding of how to proactively deploy of applicable GFM functions in VSC-HVDC projects to achieve desired system performance. Furthermore, the output of this WG is expected to guide the development of future GFM-related grid codes, including application of multiple GFM in the same network.

Scope:

The following activities will be undertaken

1. Identify the detailed GFM requirements of VSC-HVDC systems in three representative

application scenarios including:

i. VSC-HVDC connecting large-scale variable renewable energy to the power grid.
ii. VSC-HVDC interconnecting asynchronous grids,
iii. embedded VSC-HVDC.

The GFM requirements are identified in the way to fulfill the grid code regulation for both power transmission and grid enhancement, so the role of VSC-HVDC systems changing from "relying on the grids" to "supporting the grids" can be realized. This task will be coordinated with WG B4.93 which will define the high level requirements.

2. Define mandatory and optional GFM requirements associated with applications that can experience topological or operational transition between scenarios. This will include evaluation of the technical benefits and economic costs of these requirements and will provide recommendations for their integration.
3. Discuss potential implementation algorithms of the GFM capabilities of the VSC-HVDC system in each application scenario with the focus on
   a. Identifying and alleviating the trade-offs between implementation of GFM requirements and original control functions, e.g., the inertial response vs. fast active power response.
   b. Optimal control mode selection for sending-end and receiving-end HVDC substations.
4. Investigate potential solutions for the operating mode transition of the GFM-based VSC-HVDC system between different application scenarios, e.g., transition from the embedded HVDC in a meshed synchronous grid to the one interconnecting two asynchronous grids.
5. Exploring needs and feasibility of a function for seamless transition between the GFM and grid-following (GFL) control mode for the VSC-HVDC substation, such as GFM/GFL mode live switching.
6. Develop the benchmark simulation models as well as the testing specifications for each application scenario to provide the testing platforms for verifying the GFM capabilities for VSC-HVDC systems.
7. Develop a methodology to gauge the economic benefits of the GFM-related grid services provided by the VSC-HVDC systems.

Deliverables:

☒ 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) Q2 2024
- Develop final work plan Q3 2024

• Draft TB for Study Committee Review • Final TB • Webinar Start: April 2024	Q4 2026 Q1 2027 Q2 2027 **Final Report**: February 2027	
Approval by Technical Council Chair: **Date**: February 12th, 2024		

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

https://www.cigre.org/GB/about/official-documents

a. Only one member per country: by exception of SC Chair, WiE and NGN nominees.

b. WG nominees by NCs 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.