CIGRE Study committe B4

PROPOSAL FOR THE CREATION OF A NEW WORKING GROUP

JWG B4/C4.105

NAME OF THE CONVENOR
Rao Hong (CHINA)

TITLE
Benchmark Models for Multi-Infeed HVDC Studies

THE WG APPLIES TO DISTRIBUTION NETWORKS: NO

ENERGY TRANSITION
5 / Grids and Flexibility

POTENTIAL BENEFIT OF WG WORK
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

SUSTAINABLE DEVELOPMENT GOAL
0 / Other SDGs or not applied

BACKGROUND :

In the era of global energy transition, power systems worldwide are increasingly required to support cleaner, more efficient, more flexible energy transmission and grid interconnection. As the share of renewable energy grows, higher demands are placed on power system stability, operational robustness, and planning methodologies. DC and power-electronic technologies have therefore become key enablers in modern power systems.

At present, HVDC applications globally can be broadly categorized into three main areas. First, **bulk power transmission**, including long-distance, large-capacity LCC-HVDC and VSC-HVDC links for delivering energy from remote resource bases to load centers, as well as grid connections for large-scale renewable integration such as offshore wind via VSC-HVDC. Second, **grid interconnection**, where VSC-HVDC is increasingly used for asynchronous or weak-grid interconnections due to its flexible controllability. Third, **power system stability enhancement**, where power-electronic-based technologies, including grid-forming converters and FACTS devices, are actively studied and deployed to support voltage, frequency, and angle stability under high renewable penetration.

With the continued deployment of DC projects, many regions have evolved into **multi-infeed HVDC systems**, in which multiple LCC-HVDC and/or VSC-HVDC projects interact through a common AC network.

In Europe, the increasing use of VSC-HVDC for offshore wind integration and cross-border interconnections has led to emerging multi-infeed HVDC scenarios. Projects such as BorWin3 and other North Sea offshore HVDC links inject power into relatively weak onshore grids, often in close electrical proximity to existing HVDC and HVAC interconnections. In addition, VSC-HVDC back-to-back and point-to-point schemes, such as the France–Spain interconnection, contribute to complex interaction phenomena in interconnected AC systems.

In South America, particularly in Brazil, long-distance HVDC transmission has become a key solution for delivering bulk hydropower from remote regions to major load centers. Multiple LCC-HVDC bipoles currently feed power into the Southeast and Midwest AC systems, forming dense multi-infeed HVDC environments. With the planned introduction of new HVDC projects, including VSC-HVDC schemes, challenges related to commutation failures and broader AC–DC interaction remain highly relevant.

In Asia, China has developed one of the world's most extensive HVDC transmission networks, featuring a large number of UHV LCC-HVDC and VSC-HVDC projects. Multiple HVDC links inject power into major load centers over shared AC networks, forming complex multi-infeed HVDC systems. The coexistence of LCC-HVDC, VSC-HVDC, and large-scale renewable integration has made China a prominent case for studying multi-infeed interactions and system stability issues.

In India, the uneven geographical distribution of energy resources has driven the deployment of multiple HVDC links to transmit power from generation-rich regions to northern load centers. Several LCC-HVDC projects, including Rihand–Delhi, Ballia–Bhiwadi, Champa–Kurukshetra, and Biswanath Chariali–Agra, inject power into electrically proximate AC networks, forming a typical multi-infeed HVDC environment. With increasing penetration of wind, solar, and hydropower, these systems present challenges related to commutation failures and AC system stability.

Historically, the **multi-infeed Interaction Factor (MIIF)** has been used as a planning and screening index to evaluate interaction strength between any two inverter ac voltages in a power system with multiple HVDC infeed. However, the original MIIF concept and associated criteria were developed primarily for systems dominated by LCC-HVDC. With the increasing penetration of VSC-HVDC technology and FACTS devices, and the coexistence of diverse power-electronic-based resources within the same AC network, there is no widely accepted methodology that consistently applies the MIIF concept across hybrid systems. This gap limits planners', researchers', and operators' ability to assess interactions and stability in complex multi-infeed scenarios.

At the same time, although benchmark models and typical study systems have been developed by IEEE and CIGRE for specific DC applications, there remains a lack of **benchmark models tailored to multi-infeed HVDC studies**. Many academic and industry studies rely on self-developed test cases or modified standard systems with limited realism or transferability. Utility-grade models are often data-intensive and constrained by confidentiality, making comparative studies and reproducible research difficult.

Against this background, there is a clear need to develop **benchmark models and study methodologies for multi-infeed HVDC studies** that span a range of real-world scenarios. Such models should reflect mainstream DC configurations, encompass interactions among LCC-HVDC, VSC-HVDC, and relevant FACTS, and support studies on voltage, frequency, power-angle stability, and interaction indices such as MIIF. Establishing benchmark models and a methodological framework will provide a common basis for global research, facilitate result comparison, and support the development of robust planning and operational practices in the evolving power system.

The proposed work will build upon the foundational concepts established in TB 364 (WG B4.41) regarding systems with multiple DC infeed and the benchmark modeling methodologies from TB 804 (WG B4.72). It also acknowledges the findings of TB 798 (WG B4.66) on harmonic interactions and TB 934 (WG B4.81) concerning dynamic interactions between nearby converters. Furthermore, the WG will take into account the impact of AC system characteristics (B4-64), network equivalents (B4/C4.103), and transmission planning (JWG C1/B4.58) to ensure a comprehensive understanding of the multi-infeed environment.

PURPOSE / OBJECTIVE / BENEFIT OF THIS WORK :

The purpose of this work is to develop a set of benchmark models and associated study methodologies for multi-infeed HVDC studies, providing a consistent and practical technical basis for analyzing interactions and stability phenomena in modern power systems with high penetration of power-electronic-based technologies, as well as supporting future technology development.

The objectives of this working group are to:

Define representative benchmark models that capture typical multi-infeed HVDC configurations observed worldwide, including the coexistence of LCC-HVDC, VSC-HVDC, and relevant FACTS devices within shared AC networks;

Establish a unified modeling framework suitable for power system studies across different time scales, supporting assessments of interaction phenomena in multi-infeed HVDC systems, as well as AC voltage stability, frequency stability, and power-angle stability;

Review and extend the concept of MIIF beyond its traditional application to LCC-HVDC systems, and develop a consistent study methodology applicable to hybrid systems involving VSC-HVDC and FACTS, with clear assumptions, limitations, and use cases;

Provide guidance on the application of the benchmark models and methodologies for planning and comparative studies, enabling reproducible and transparent analysis across academia, utilities, and manufacturers.

Address the trade-off between model realism and proprietary information protection. The WG will investigate methodologies for black-boxing and generic model enhancement to ensure benchmark models remain valuable without compromising Intellectual Property (IP).

SCOPE :

This working group, titled "Benchmark Models for Multi-Infeed HVDC Studies," aims to develop benchmark models and study methodologies to support research and analysis of interaction and stability phenomena in multi-infeed HVDC systems. The scope of work includes the following activities:

1.Global survey of multi-infeed HVDC scenarios and typical applications

Survey and summarize representative multi-infeed HVDC application scenarios worldwide, considering differences in grid characteristics, HVDC technologies, and operational contexts across regions. The survey will focus on identifying typical multi-infeed configurations and interaction characteristics, rather than project-specific engineering details.

2.Review of modeling and simulation practices and interaction assessment approaches

Conduct a review of existing DC system simulation practices and commonly used interaction assessment approaches for multi-infeed HVDC systems. Particular attention will be given to the historical use of the MIIF in LCC-HVDC-dominated systems, as well as current challenges when extending such concepts to hybrid systems involving VSC-HVDC and FACTS.

3.Development of benchmark models for multi-infeed HVDC studies

Based on the findings from Activities 1 and 2, develop a set of benchmark models applicable to typical multi-infeed HVDC scenarios. The models will be designed to represent interactions among LCC-HVDC, VSC-HVDC, and relevant FACTS devices within shared AC networks, balancing modeling simplicity and practical relevance. Model structures and assumptions will be validated through consistency checks and comparative simulation studies.

4.Study methodology for interaction and stability analysis

Establish a consistent study methodology using the developed benchmark models to analyze multi-infeed HVDC interactions and key stability aspects, including AC voltage stability, frequency stability, power-angle stability, and interaction indices such as MIIF. The applicability, interpretation, and limitations of MIIF in hybrid multi-infeed HVDC systems will be examined, without defining mandatory planning thresholds.

5.Documentation and dissemination

Summarize the survey results, modeling principles, benchmark models, and study methodologies in a technical report and supporting documentation. The deliverables will provide guidance on appropriate use cases and limitations, facilitating reproducible studies and comparative analysis across industry and academia.

This scope focuses on modeling frameworks and analytical methodologies rather than detailed engineering design or control implementation, with the objective of providing a common technical foundation for studying multi-infeed HVDC systems in evolving power networks.

Limitation of Scope:

This working group focuses on modeling frameworks and study methodologies for multi-infeed HVDC systems and does not aim to develop detailed engineering designs, control algorithms, or project-specific solutions. The benchmark models developed in this work are intended as reference for analysis and comparative studies, rather than as templates for direct implementation in practical projects.

The study of MIIF within this working group is limited to methodological evaluation and interpretation in hybrid systems involving LCC-HVDC, VSC-HVDC, and FACTS. The working group will not define mandatory planning criteria, numerical thresholds, or compliance requirements related to MIIF or other interaction indices.

The scope of this work emphasizes generic and globally applicable scenarios, and does not target the conditions of any specific country, utility, or project. Regional examples are used solely for illustrating typical multi-infeed configurations and interaction phenomena.

While power-electronic-based resources beyond HVDC and FACTS, such as inverter-based generation, may be referenced to assess the potential extensibility of the proposed methodologies, detailed modeling or control studies of such resources are outside the scope of this working group.

Remark:

The outcomes of this work are intended to complement existing CIGRE technical activities, providing a common analytical foundation that may support future research, recommendations, or standardization efforts, without duplicating or superseding ongoing or completed work.
This working group will maintain communication with relevant CIGRE and IEEE technical bodies, as appropriate.
Special attention will be given to promoting the development of benchmark models as globally applicable references.
The working group will also consider the relationship between detailed vendor-specific (“as-built”) models and benchmark generic models in multi-vendor environments, and provide guidance on their complementary use.

DELIVERABLES AND EVENTS

Deliverables Types
Annual progress and activity report to Study Committee
Electra report

Future connections
Technical Brochure and Executive Summary in Electra
Tutorial

Time schedule

Q1	2026	Recruit members
Q2	2026	Develop final work plan
Q3	2027	Draft TB for SC review
Q1	2028	Final TB
Q2	2028	Tutorial

APPROVAL BY TECHNICAL COUNCIL CHAIRMAN:
Rannveig Loken
March 27th, 2026