CIGRE Study Committees B4 and C4

PROPOSAL FOR THE CREATION OF A NEW WORKING GROUP

JWG [1]N° B4/C4.103	**Name of Convenor:** Hiranya Suriyaarachchi (CANADA)
Strategic Directions #[2]: 1,2,3	**Sustainable Development Goal #[3]:7,9,11,13**

The JWG applies to distribution networks: ☐ Yes / ☒ No

This Joint Working Group addresses these Energy Transition topics:

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

Potential Benefit of JWG work #[4] : 1,2,3,4,5

Title of the Group: AC Network Equivalents for HVDC and FACTS Project Studies

Scope, deliverables and proposed time schedule of the WG:

Background:

Electromagnetic Transient (EMT) domain simulations based on reduced AC system network representation (AC system equivalents) have been widely used by HVDC/FACTS OEMs for HVDC and FACTS projects to design and verify their system performance such as control and protection (C&P) to meet the specified performance and control functionality in terms of AC/DC fault recovery, modulation, overvoltage/undervoltage protection etc.

As the energy transition is changing the landscape of the power systems,.one of the major changes is the rapid growth of inverter-based resources (IBR). This rapid growth results in a fundamental change in the characteristics of the AC system. HVDC and FACTs systems are enablers of the energy transition as they facilitate the integration of IBR. Further, during the life of an HVDC or FACTS project, the AC system continues to change due to the addition of more power-electronic devices and the retirement of synchronous machines based on fossil fuel-based generation.

As a result of these changes, there is a high risk of having phenomena such as control interaction or harmonic stability, which may go undetected with the traditional study methodologies. Therefore, these studies require Electromagnetic Transient (EMT) domain simulations. The usage of a large-scale EMT model may not be practical due to reasons such as computation burden, speed of simulation, and confidentiality constraints. In such situations, AC system equivalents of selected areas are used.

It is important to accurately represent the dynamic performance of the AC network at the point of connection of the Power Electronic (PE) device in the AC network equivalent as closely as possible to the original network. To achieve this, appropriate modelling techniques need to be used. As traditional synchronous generators are replaced by non-conventional devices, the development of AC equivalents becomes challenging. When developing equivalents for present-day AC networks, one needs to consider the presence of devices such as IBRs, Distributed Energy Resources (DERs), traditional dynamic loads, inverter-based loads (IBLs) and other PE devices. Also, due to restrictions with model sharing, the availability of accurate models of these devices to the AC equivalent developer would be limited. Furthermore, the challenging timelines associated with the HVDC and FACTS projects (e.g. design studies, root cause analysis) would require AC equivalents which are not too large and fast, to be developed in a short time with a sufficient degree of accuracy.

Although AC system equivalents are being used for performing studies for HVDC systems and FACTS devices, the modelling techniques and processes used to develop AC network equivalents are not well documented. Also, the adequacy and applicability of traditional equivalencing methods to the present-day AC networks need to be re-evaluated. Furthermore, the adequacy and applicability of new modelling techniques such as co-simulation need to be assessed. At present a guideline on developing AC network equivalents for modern power systems is not available.

Purpose/Objective/Benefit of this work:

The objective of this working group is to provide guidelines for developing AC system equivalents in EMT tools for studying HVDC systems or FACTS devices. Both static and dynamic equivalents as well as other modelling techniques such as co-simulation[1] will be considered and recommendations on how to determine the size of the equivalent AC network and benchmarking against the original model will also be presented.

Although the main focus of the this WG is HVDC and FACTS studies, the outcome of this WG may be possible to directly apply to development of network equivalents for some large scale IBR projects (e.g. Offshore wind farms). This working group will highlight when the developed guidelines can be applied to IBR study context and limitations.

Scope:

The working group would investigate and report on:

1. Review the AC network equivalencing and identify the gaps in the existing methodologies and approaches.
2. Discuss the application of AC network equivalents for various HVDC and FACTS studies and their limitations.
3. Discuss methods to determine the size of the network equivalent considering the type of the study (e.g. dynamic performance, harmonic performance, Insulation coordination), and the AC network characteristics.
4. Review the existing methods and propose modelling methods of the network elements based on the type of studies performed. For example,
    a. Frequency-dependant characteristics of transmission lines and cables
    b. Inverter-based resources
    c. Dynamic loads
    d. FACTS devices
    e. DERs
5. Propose benchmarking methods to evaluate the adequacy of the AC network equivalents. The indicators highlighting the following system characteristics will be considered.
    a. Steady-state performance
    b. System impedance
    c. Short-circuit level
    d. System inertia

[1] In Co-simulation techniques, only a portion of the AC system is modelled in EMT domain and the remainder of the network is modelled in phasor domain.

e. Dynamic performance following disturbances
6. Provide recommendations on the significance/relevance of the proposed benchmarking methods for the type of EMT study to be conducted with the AC network equivalent in EMT.
7. Provide recommendations on the required level of accuracy which can be considered adequate for the acceptability of EMT equivalent.
8. Requirement on the Input data. For example,
    a. Quality of the Phasor-Domain Transients (PDT) models
    b. Level of details of (e.g., bus bar configurations, medium and low voltage network details)
    c. EMT modelling details
9. Discuss recommendations with regards to practical implementation: Challenges for different stakeholders (Manufacturers, Network Owners, Developers, and consultants) with respect to aspects such as timelines, data availability and possible solutions.
10. Discuss the applicability of the recommendations/guidelines to IBR projects and identify any gaps.

References:

I. TB881: Electromagnetic transient simulation models for large-scale system impact studies in power systems having a high penetration of inverter-connected generation (This TB discusses the use of EMT models to perform large-scale system impact studies in power systems with high penetration of inverter-based generation)
II. WG B4.81: Interaction between nearby VSC-HVDC converters, FACTs devices, HV power electronic devices and conventional AC equipment (T*his WG will be investigating the Interactions between nearby VSC-HVDC converters, FACTs devices, HV power electronic devices and conventional AC equipment and propose appropriate study methods*)
III. WG C4.64: Application of Real-time Digital Simulation in power systems (*This WG includes a deliverable of a discussion and a comparison of methods used to create dynamic and frequency-dependent equivalents for real-time simulation. However, in the real-time simulation, a major constraint is the simulation hardware limitation which determines the size of the network equivalent*)
IV. JWG B4-C4.97: Benchmarking of simulation Models for control interaction in meshed AC networks with multiple converters (*This WG will be developing benchmarking models to evaluate the control interactions in meshed AC networks*)

The JWG will liaise with the aforementioned ongoing working groups to ensure the TB scopes are coordinated.

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) • Develop final work plan • Draft TB for Study Committee Review • Final TB • Tutorial • Webinar	Q2 2024 Q3 2024 Q3 2026 Q1 2027 Q3 2027 Q2 2027
Approval by Technical Council Chairman: **Date**: May 13th, 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 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.