CIGRE Study Committee C4

PROPOSAL FOR THE CREATION OF A NEW WORKING GROUP

WG[1] N° C4.65	**Name of Convenor:** Jason David (AUSTRALIA) **E-mail address**: jasond@uow.edu.au	
Strategic Directions #[2]: 1	**Sustainable Development Goal #[3]: 7, 9**	
The WG applies to distribution networks: ☒ **Yes** / ☐ **No**		
Potential Benefit of WG work #[4] : 2, 3		
Title of the Group: Specification, Validation and Application of Harmonic Models of Inverter Based Resources		

Scope, deliverables and proposed time schedule of the WG:

Background:

Connection of large-scale renewable energy sources (RES) such as solar and wind systems interfaced through Power Electronic (PE) converters are on the rise around the world. Harmonic compliance studies take a prominent place with regard to such connections where vendor provided Norton/Thévenin harmonic models are usually employed. A frequency domain harmonic model of a single converter/inverter can be developed using a variety of techniques including those described in Section 7.3 of IEC TR 61400-21-3:2019, CIGRE Technical Brochure (TB) 766, field/test lab measurements, electromagnetic transient (EMT) simulations, undertaking calculations or some combination of all these approaches. These Norton/Thévenin models allow studies to be completed with limited computational burden. However, it is currently unclear whether the use of such a fixed model is valid under a range of converter/inverter operating conditions, grid impedance conditions, or multi converter/inverter environments in large RES connections which also include internal reticulation networks (transformers, underground cable systems, harmonic filters etc.). Comparative simulation studies undertaken indicate that there can be appreciable disagreement between the outcomes based on fixed Norton/Thévenin models with those established using detailed EMT models. Some techniques, such as the use of look-up tables to represent the harmonic behaviour at different operating points, were suggested in TB 766, however, this approach rapidly increases the complexity of analysis when multiple PE devices need to be considered. As a result, most practical studies are based on assumed “worst-case” conditions. While TB 766 provided guidelines for accurate modelling of network components on a system wide basis, it appears that a follow up document is needed to provide guidelines for development of accurate (validated) and standardised methods for PE converter models suitable for harmonic studies in the frequency domain that are supported by sound engineering judgement and experience. Such processes should also be amenable to equipment vendors.

It is noted that there are several currently active working groups with opportunity for collaboration, such as WG C4.49, C4.56 and C4.60. C4.49 and C4.56 are focusing on particular phenomena such as harmonic instability and transient interactions. The outcomes of these WGs are complementary to the activities of this proposed WG and have the potential to provide useful input.

WG C4.60 aims to develop generic EMT models of PE converters for the purpose of long term planning and its scope is quite broad. A direct correlation between this WG and work undertaken by C4.60 is possible. It is suggested that collaboration would benefit both WGs as one of the key developments of this proposed WG is to provide comprehensive, standardised modelling processes specific to individual converters, or a collection of converters for harmonic compliance studies. Whilst the outcomes of both groups are likely to complement each other, the incentive and critical outcomes are considerably diverse and hence significant.

Scope:

1) Summarise existing approaches and industry practices used (technical documents, guidelines etc.) in pre-compliance steady-state harmonic emission studies conducted on large solar and wind farms. List advantages and disadvantages of the approaches used and establish the level of confidence placed on vendor provided harmonic models. This is to include approaches such as RMS modelling in the harmonic domain, EMT modelling, hybrid RMS/EMT processes.

2) Collate methods followed by vendors in the development of harmonic domain Norton/Thévenin (or other equivalent) models of converters/inverters (including positive, negative and zero sequence variations) used in large wind and solar farms. Establish evidence of comparison with field measurements and EMT models as provided by vendors. This task may be undertaken in conjunction with WG C4.49 and/or C4.60.

3) Quantify discrepancies observed, e.g. determine degree of error associated with using vendor provided Norton/Thévenin or other equivalent models compared with actual measured values.

4) Determine margin of error of harmonic domain models due to operational variations such as converter/inverter set-points and external conditions such network characteristics and power quality (PQ) emission levels, e.g. background harmonic distortion and other PQ emission levels, SCR at the PCC and harmonic cross-coupling aspects.

5) Collate outputs of existing working groups C4.49, C4.56 and C4.60, i.e. EMT type simulation models that can replicate the practical behaviour of converters/inverters in relation to steady-state harmonic emissions. Compare their results with the outcomes from vendor provided Norton/Thévenin models.

6) Reach overall conclusions based on observed technical efficacy related to the robustness of modelling processes such as Norton/Thévenin equivalent models, EMT modelling and hybrid RMS/EMT models for the purpose of undertaking steady-state harmonic emission compliance studies.

7) Specify appropriate processes to develop and validate adequate Norton/Thévenin or other equivalent models, make suggestions/updates based on findings of previous items or provide pragmatic alternatives to allow harmonic emission studies to be undertaken that meet required accuracy bounds without significantly increasing time required to undertake such studies.

Liaison member from SC B4 will be appointed.

Deliverables:

☒ Technical Brochure and Executive Summary in Electra

☒ Electra Report
☐ Future Connections
☐ CSE
☒ Tutorial
☒ Webinar

Time Schedule: start: Q3 2021	**Final Report**: Q3 2024
Approval by Technical Council Chairman:	Marcio Szechtman
Date: April 11th, 2021	

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

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.