CIGRE Study Committee C4

PROPOSAL FOR THE CREATION OF A NEW WORKING GROUP

WG N° C4.76	**Name of Convenor:** Qing Yang (China)	
Strategic Directions #[2]: 1, 2, 4	**Sustainable Development Goal #[3]:** 7, 9	
The WG applies to distribution networks: ☒ **Yes /** ☐ **No**		
Potential Benefit of WG work #[4] : 1, 3, 4		
Title of the Group: Overvoltage Protection in Switching Inductive Devices with Vacuum Circuit Breaker		

Scope, deliverables and proposed time schedule of the WG:

Background:

Vacuum circuit breakers (VCB) are widely used in the medium voltage (MV) power systems because of its excellent performance, and it is also used in partly high voltage (HV) systems due to its environmental friendliness. In the MV and HV power system, including the offshore wind farm, distribution network, and transmission network, VCBs are applied to switch inductive devices, such as transformers, motors, shunt reactors, arc suppression coil, transmission line, etc. Especially with the development of new energy systems, the switching of reactive power compensation becomes more frequently because of the uncertainty of load. However, when VCB is switching inductive loads, there is a high probability of generating high-frequency and high-amplitude overvoltage. The overvoltage caused by switching will propagate along the line or the bus, which can cause various accidents such as explosions of VCB, insulation damage of transformers, and shunt reactors. These accidents have been reported in China, Denmark, and other countries in recent years. When the VCB interrupts the current, the capacitor and inductance circuit will generate a high-frequency oscillation, which leads to the chopping overvoltage. Also, when the contact distance is small during the VCB switching on, the high-frequency restrikes/prestrikes cause overvoltage. Limited by the experimental conditions, complexity, and randomness of the transient process, the measurement, simulation, and suppression of switching overvoltage are still problems that need to be solved. Although CIGRE working group 13.02 completed significant amount of work, there are still some challenges in electromagnetic transient characteristics, transient models, and the selection of overvoltage suppression measures.

(1) <u>Electromagnetic Transient Characteristics</u>

Accurate measurement of switching overvoltage is the basis for the electromagnetic transient analysis. High steepness and high frequency overvoltage can be generated by switching off/on reactive power compensation devices, which puts forward higher requirements for the design of the overvoltage measurement or monitoring system. In view of the obtained high-resolution switching overvoltage waveforms, the transient characteristics of the switching overvoltage such as frequency, amplitude, and steepness are extensively focused. The transient characteristic values are related to the system parameters, resulting in the complexity of electromagnetic transient characteristics. In recent years, high proportion of distributed generations (DGs) has been connected to the traditional distribution network. The fluctuation of node voltage caused by the output power change of DG and the harmonic caused by power electronic devices will also affect the electromagnetic transient characteristics of switching overvoltage. The electromagnetic transient characteristics of switching overvoltage in the new distribution network will superimpose the effect of DG, and the electromagnetic transient characteristics are more complex. The complex transient waveform shapes are not all included in the insulation coordination standard for winding equipment (motor or transformer), in which case new tests are required, which are critical for the reliability assessment of the equipment. In addition, data on switching overvoltage caused by VCBs in HV transmission systems are scarce compared to MV distribution networks. It is valuable to establish an overvoltage sharing database under HV transmission scenarios.

(2) Electromagnetic Transient Models

To simulate switching overvoltage, the transient VCB model which can reflect the restrike/prestrike transient process is the most significant. The restrike/prestrike effect may cause oscillation in the inductance circuit and severely damage the equipment. The accuracy of restrike/prestrike simulations hinges upon the precise modelling of parameters, including the chopping current, breakdown curve, high-frequency arc extinguishing capability, etc. Numerous researchers have strived to enhance the accuracy of VCB models by fitting model parameters using field data and accounting for the dispersion of breakdown voltage and the nonlinearity of contact motion. However, due to the variety of VCB models under different circuit topologies, it is very difficult to accurately obtain the transient modelling parameters of VCB in a required situation. To expand the applicability of VCB transient models across various voltage levels, close collaboration with manufacturers becomes indispensable to obtain the necessary test data for modelling purposes. Based on this, establishing reference guidelines for input data values in different modelling approaches and assessing the sensitivity of input parameters to model outputs are crucial steps. It is imperative to validate the accuracy of the reference values by conducting measurements in actual MV and HV systems. These endeavours are vital in improving the universality of existing VCB transient models.

(3) Suppression measures of the switching overvoltage

The common suppression measures of switching overvoltage are the installation of lightning arresters and RC snubbers. It is important to note that if a high-amplitude and high-steep overvoltage occurs during switching, the insulation level of these suppression devices may gradually deteriorate due to cumulative effects. While surge arresters can limit the amplitude of the overvoltage, they have limited impact on the restrike/prestrike effect in the VCB. Although RC snubbers can effectively suppress the restrike/prestrike effect, their withstand voltage levels are relatively low. Furthermore, the reduction of switching overvoltage amplitude can also be achieved by improving the structure, materials, and point on wave (POW) control of VCBs. These suppression measures are typically implemented in combination rather than individually. It is crucial to develop comprehensive standards and guidelines that encompass the combined use of these commonly employed suppression methods. This will ensure the effective implementation of overvoltage suppression measures in MV and HV systems. Moreover, considering the influence of cable parameters, clear recommendations and procedures should be established regarding the installation positions of lightning arresters and RC snubbers. To summarize, a holistic approach to overvoltage suppression should include the reasonable installation of lightning arresters, RC snubbers, as well as the use of POW controlling of VCBs.

Scope:

1. Summarize on-site switching overvoltage measurement results of VCBs in MV and HV power systems, establish a shared database of switching overvoltage waveforms and provide characteristic information such as the shape, amplitude, steepness, and

oscillation frequency of switching overvoltage in various typical application scenarios .

2. Accumulate test data of VCBs, by cooperation with manufacturers, provide reference for input parameter values of VCB transient model of typical models under different voltage levels and analyse the sensitivity of input parameters to model output results. Validate the plausibility of reference values by field measurements in MV and HV systems.
3. Develop comprehensive standards and guidelines for the combined use of lightning arresters, RC snubbers, and the use of POW switching to effectively suppress switching overvoltage in MV and HV systems, while considering cable parameters and installation positions, ultimately ensuring reliable overvoltage protection.

Remarks:

Due to the transversal nature of the subject matter, liaison members from SC A3 will be invited to support the work.

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)	Q4 2023
• Develop final work plan	Q4 2023
• Draft TB for Study Committee Review	Q3 2026
• Final TB	Q4 2026
• Tutorial	Q4 2026
• Webinar	Q4 2026

Approval by Technical Council Chairman:

Date: July 31st, 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

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

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.