CIGRE Study committe D1
PROPOSAL FOR THE CREATION OF A NEW WORKING GROUP

WG D1.86

NAME OF THE CONVENOR
Chen Jie (CHINA)

TITLE
Industrial Application of Radiographic Imaging Technology for High-Voltage Power Equipment Insulating Materials

THE WG APPLIES TO DISTRIBUTION NETWORKS: YES

ENERGY TRANSITION
3 / Digitalization
4 / Sustainability and Climate Change

POTENTIAL BENEFIT OF WG WORK
2 / potential interest from a wide range of stakeholders
3 / likely to contribute to new or revised industry standards
4 / state-of-the-art or innovative solutions or directions
5 / Guide or survey on techniques, or updates on past work or brochures
6 / work likely to contribute to improve safety

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
9 / Industry, innovation and infrastructure

BACKGROUND :
The reliability of high-voltage power equipment depends strongly on the integrity and long-term stability of its insulating materials, components and interfaces, including epoxy resin composites, oil-paper insulation, cross-linked polyethylene, silicone rubber, electrical ceramics and multi-material assemblies. Internal defects and abnormal conditions such as voids, delamination, cracks, foreign inclusions, density inhomogeneity, component displacement, interface separation, dimensional deviations and assembly errors may lead to partial discharge, local overheating, mechanical deterioration or, in severe cases, electrical breakdown.

Radiographic Imaging should be considered as an integrated family of complementary non-destructive inspection methods. Traditional film radiography, computed radiography (CR) and digital radiography (DR) produce two-dimensional projection images and are already used for manufacturing quality control and selected field inspections. Typical applications include insulating components, cable accessories, factory and subsea-cable joints, gas-insulated metal-enclosed switchgear, bushings, cable sealing ends and terminations, basin-type insulators and insulating rods. Field radiography can reveal foreign objects, component displacement, assembly abnormalities, external mechanical damage, cable buffer-layer damage and stress-cone displacement.

Portable X-ray generators are generally preferred for field work because they can be switched off and controlled directly. In selected applications, sealed gamma-ray sources may provide a smaller and more easily positioned source and can, for suitable inspection geometries, reduce the required exclusion-zone dimensions compared with some portable X-ray arrangements. Their use must nevertheless be justified against penetration and image-quality needs, exposure time, source security, transport, licensing, shielding and radiation-protection requirements.

Industrial computed tomography (CT) extends projection imaging by acquiring views from multiple directions and reconstructing three-dimensional information. Laboratory micro-CT, high-energy CT, large-object CT, limited-angle tomography and mobile or dedicated CT systems are increasingly used for materials research, manufacturing evaluation and failure investigation. CT can determine defect location, size, morphology and spatial distribution, assess interfaces and dimensional deviations, and clarify the spatial relationship between damage and surrounding structures. This is particularly valuable in forensic failure analysis and root-cause determination. Applications to large or in-service equipment remain constrained by component dimensions, material attenuation, metal artefacts, restricted access, reconstruction uncertainty, inspection time and on-site radiation safety.

The power industry currently lacks a common application framework that links inspection purpose, required detectability and sensitivity, process stage, component and material characteristics, method selection, system configuration, image-quality verification, data interpretation, engineering acceptance and reporting. The Working Group will therefore begin with established radiographic practice, then examine present and emerging CT capabilities, and combine both within an application-oriented study supported by representative manufacturing, field and failure-investigation cases.

PURPOSE / OBJECTIVE / BENEFIT OF THIS WORK :

The purpose is to establish a common technical framework and practical application guideline for the industrial use of X-ray imaging for high-voltage insulating materials and components. The work will define what defects and abnormal conditions should be detectable, how application-specific sensitivity and image quality should be specified and verified, and which research, manufacturing, field-diagnostic, maintenance and failure-investigation processes the methods should support. It will help users select suitable imaging methods, sources, detectors and inspection configurations; improve the consistency, safety and reliability of inspection and interpretation; and identify priorities for future technology development, validation and standardisation.

SCOPE :

The Working Group will investigate and report on:

1. **Traditional Radiography-Technical Framework, State of the Art and Applications:** The historical development, principles and current status of film radiography, CR and DR for high-voltage insulating materials and components will be reviewed. The study will cover manufacturing quality-control applications, including insulating components, cable accessories, factory joints and subsea-cable factory joints, as well as selected field applications to bushings, cable sealing ends and terminations, GIS, basin-type insulators, insulating rods and other installed equipment. Relevant CIGRE D1 work, standards, published research and established industrial practice will be reviewed, together with the relationship between projection radiography and CT.
2. **Inspection Requirements and Performance Targets:** Requirements will be described for different materials, component types and process stages. The work will identify the defects and abnormal conditions to be detected; the required penetration, spatial resolution, contrast sensitivity, dimensional accuracy, inspection coverage and detection reliability; and the processes to be supported, including material and process development, manufacturing quality control, factory acceptance, field diagnosis, maintenance decision-making and forensic failure investigation. Because achievable sensitivity depends on material composition, thickness, geometry, defect orientation and inspection configuration, the study will distinguish between application-specific demonstrated capability, sensitivity-verification methods and generally applicable minimum provisions. Representative performance ranges will be reported where sufficiently validated evidence is available.
3. **Industrial CT - History, Current Technology, Applications and Future Feasibility:** The development, principles and present technical status of industrial CT will be reviewed, including laboratory micro-CT, high-energy CT, large-object CT, limited-angle tomography and mobile or dedicated systems. Current applications in material research, manufacturing assessment, dimensional metrology, defect characterisation and failure investigation will be examined. The study will also assess what is technically feasible for future application to large, complex or in-service high-voltage equipment, including sparse-view and limited-angle reconstruction, robotic positioning, automated image-quality assessment, AI-assisted interpretation and multimodal data fusion.
4. **Imaging Systems, Inspection Configurations, Source Options and Radiation Safety:** The Working Group will examine X-ray generators, sealed gamma-ray sources used for radiography in selected field situations, detectors, geometric arrangements, positioning systems, acquisition functions and CT reconstruction systems used in stationary, laboratory, portable and field-deployable configurations. The assessment will consider penetration capability, spatial resolution, contrast sensitivity, exposure time, equipment positioning, access limitations, shielding, controlled-area and exclusion-zone requirements, source transport and security, operating licences and radiation protection.
5. **Materials, Defects, Image Quality and Evaluation:** The imaging characteristics of epoxy resin composites, oil-paper insulation, cross-linked polyethylene and other polymeric cable insulation, silicone rubber, electrical ceramics and multi-material interfaces will be investigated. Typical defects and abnormal conditions will include voids, metallic and non-metallic inclusions, delamination, cracks, density inhomogeneity, deformation, internal component displacement, interface separation, dimensional deviation, assembly errors, cable buffer-layer damage and foreign objects in enclosed equipment. Image evaluation will address image-quality indicators, spatial and contrast resolution, detectability, geometric magnification, artefacts, measurement uncertainty, qualitative interpretation and, where technically justified, quantitative characterisation.
6. **Failure Investigation, Forensic Analysis and Representative Case Studies:** Representative cases will be collected from manufacturing quality control, field diagnosis and equipment failure investigation. Particular attention will be given to cases in which CT or complementary radiographic methods support the progression from symptom identification and defect localisation to structural assessment, root-cause determination and corrective

action. Cases will also illustrate practical constraints, unsuccessful or ambiguous results where appropriate, and the complementary use of projection imaging and CT when full rotational scanning is not possible.
7. **Application Guidance, Technical Boundaries and Future Development:** An application-oriented method-selection framework will be developed based on the inspection objective, required detection performance, component dimensions, material composition and attenuation, expected defect, process stage, accessibility, available equipment and site conditions. The Working Group will assess technical maturity and application limits, define image-quality and sensitivity-verification provisions, summarise interpretation and reporting principles, and identify needs for further research, technical validation, CIGRE guidance and international standardisation.

Remarks

- Safety requirements for the use of ionising radiation sources in the field and laboratory settings differs between jurisdictions. A detailed review of such regulations is outside the scope of this WG. However, some general principles will be included.
- Liaisons from other study committees are welcome, since this work applies to may plant types.

DELIVERABLES AND EVENTS

Deliverables Types

Annual progress and activity report to Study Committee
Future connections
Technical Brochure and Executive Summary in Electra
Tutorial

Time schedule

Q4	2026	Recruit members (National Committees, WiE, NGN)
Q1	2027	Develop final work plan
Q2	2029	Draft TB for Study Committee Review
Q1	2030	Webinar

APPROVAL BY TECHNICAL COUNCIL CHAIRMAN:

Rannveig S. J. Loken
November 22nd, 2026