CIGRE Study committe A2

PROPOSAL FOR THE CREATION OF A NEW WORKING GROUP

WG A2.78

NAME OF THE CONVENOR
PATEL Poorvi (UNITED STATES OF AMERICA)

TITLE
Bushing Diagnostics: Off-Line Testing and On-Line Monitoring Systems

THE WG APPLIES TO DISTRIBUTION NETWORKS: YES

ENERGY TRANSITION
3 / Digitalization

POTENTIAL BENEFIT OF WG WORK
3 / likely to contribute to new or revised industry standards
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
0 / Other SDGs or not applied

BACKGROUND :
The reliability and predictability of power transformers are of utmost importance for utilities. These assets are costly and often have long lead times for replacement. According to CIGRE Technical Brochure 939 (2024), about 25% of transformer failures are due to bushings, making them one of the “weak links” in transformers. Additionally, CIGRE Technical Brochure 755 (2019) on Transformer Bushing Reliability provides a good description of typical bushing failure modes and their root causes.

There is a need to establish a comprehensive approach incorporating both off-line testing methodologies and on-line monitoring of bushings to identify early signs of deterioration and prevent unexpected failures.

With increased electrification, load growth, and supply chain constraints, utilities must ensure transformers and their accessories, such as bushings, are in good working condition to avoid unexpected failures, loss of load, and long replacement times. The energy transition has led to higher transformer loading and more dynamic operational profiles, resulting in an increased occurrence of thermally induced bushing issues. Additionally, there have been reports of failures in unaged bushings, especially from renewable energy installations with highly cyclic loading and temperature variations.

Today, oil-filled (OIP) and dry-type bushings (RIP, RIS, RBP) are commonly used. Diagnostics for oil-filled bushings are well established, whereas reliable diagnostic methods for dry-type bushings remain limited. There is a gap in understanding how off-line testing and on-line monitoring systems can detect deteriorating dry-type bushings early. Emerging diagnostic techniques, such as Dielectric Frequency Response (DFR), advanced Partial Discharge (PD) monitoring, and Infrared Thermography, require further validation through real-world case studies.

IEEE C57.12.200 DFR on Bushings, released in 2018, showed few cases for OIP bushings. More cases from different parts of the world are needed to understand how climate patterns affect bushing conditions.

PURPOSE / OBJECTIVE / BENEFIT OF THIS WORK :

The key benefit of this brochure is to provide a comprehensive document on bushing diagnostics, including both off-line and on-line testing technologies, and the types of bushing issues that can be detected and analysed. The document will also collect bushing cases to assist engineers in the field, providing guidelines for interpretation and decision-making. The bushing testing technologies to be expanded on include DFR, DGA, 50/60 Hz Capacitance and Power Factor Testing, and Partial Discharge testing. Emerging diagnostic technologies, including artificial intelligence (AI) and machine learning-based analytics, for predictive bushing failure assessment is also proposed to be included. Understanding cases where condition changes occur during operation and are detected by bushing monitoring systems will enhance predictive maintenance strategies and benefit the industry by reducing unexpected failures and optimizing asset lifecycle management.

SCOPE :

Describe different off-line and on-line testing technologies and recommended practices for bushing testing and analysis:

- DFR
- 50/60 Power Factor and Capacitance
- DGA
- PD-testing
- IR-thermographic
- Other technologies, if any

Discuss the different bushing capacitance and power factor monitoring methods and the data processing and interpretation:

- Sum of Current
- Absolute Power factor
- Reference method
- Other methodologies
- Alarm and threshold levels

Collect cases where off-line testing and/or on-line monitoring detected bushing issues and were confirmed by forensic investigation:

- Consider various technologies such as OIP, RIP, RIS, and RPB
- Comparison of bushing failures in various transformer and reactor types
- Criteria variation depending on voltage class
- Importance of monitoring cases to demonstrate the value of installing sensors
- User reaction time and failure mechanisms

Cases would include:

- Contamination of bushings (Cu2S, X-wax)
- Dielectric puncture of bushings (shorted capacitive layers)
- High moisture ingress in bushings
- Cold climate bushings issues (e.g. cracking, condensation)
- Comparison between on-line versus off-line testing
- Comparison with FAT or SAT testing
- Installation related failures, such as improper torque application or contamination during commissioning
- Issues due to improper storage of bushings (especially RIP bushings)
- Bushing issues from renewable sites (impact of cyclic temperature fluctuations and intermittent loading conditions)
- Testing effected by external influences (Ice and snow, wet bushing surface, improper cleaning agent, dust and contamination of bushing surface, external corona, etc.)

Remarks:

The WG should consider publishing an interim report to share the main results as soon as they become available.

DELIVERABLES AND EVENTS

Deliverables Types

Annual progress and activity report to Study Committee

Electra report
Technical Brochure and Executive Summary in Electra
Tutorial
Webinar

Time schedule

Q1	2025	Recruit members (National Committees, WiE, NGN)
Q2	2025	Develop final work plan
Q4	2028	Draft Technical Brochure for Study Committee review
Q1	2029	Final draft Technical Brochure
Q1	2029	Tutorial
Q1	2029	Webinar

APPROVAL BY TECHNICAL COUNCIL CHAIRMAN:
Rannveig S. J Loken
March 18th, 2025