CIGRE Study Committee B4

PROPOSAL FOR THE CREATION OF A NEW WORKING GROUP

WG [1]N° B4. 89	**Name of Convenor: Nadine Chapalain** (France) **E-mail address**: n.chapalain@fr.merce.mee.com

Strategic Directions #[2]: 1,2	**Sustainable Development Goal #[3]: 9**

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

Potential Benefit of WG work #[4] : 1,3,5,6

Title of the Group: Condition Health Monitoring and predictive maintenance of HVDC Converter Stations

Scope, deliverables and proposed time schedule of the WG:

Background:

Ensuring a high level of in-service availability of HVDC stations is the top priority for transmission network operators. The concept of scheduled maintenance to replace equipment or components in the system, considering it as weak or that it could lead to future failure should be improved. Today, new approaches of maintenance strategies are explored to improve the power system reliability, increase their stability and reduce the operating costs. Condition Health Monitoring (CHM) is effective for improving the availability of power electronic components and systems by monitoring their state and estimating their health. It enables the planning for optimal maintenance schedule (cost and availability wise). These new approaches are based on monitoring and diagnosis to predict maintenance and the possibility of extending the life of existing assets.
With increasing bulk power transfer and largescale renewable integration, voltage source converter (VSC) are key equipment. VSC uses a high number of power semiconductor devices, capacitors, electrics, and insulation components. The condition of the power electronic components is important for the reliability of the complete system. Therefore, it is evident that CHM would play a crucial role in predicting the maintenance of HVDC power electronic based assets but also at system level since health indicators may vary depending on the application (e.g. HVDC, FACTS) and location profile (e.g. offshore, onshore).

In the context of reliability Cigre SC B4 (AG B4.04) reports annually the performance data on energy availability, energy utilization, forced and scheduled outages of HVDC systems in commercial service throughout the world. In 2011, WG B4.48 (TB 447) reported on component testing of VSC systems and stated that the steady-state stresses on components are mainly influenced by the operating modes, topology, modulation strategy, the equivalent reactance of the ac system and by the characteristics of the dc transmission system (i.e. overhead lines or cables).

Guidelines for life extension of existing HVDC systems were reported by WG B4.54 in 2016 (TB 649) and in 2017, WG B4.60 concluded that the long term reliability of the converter stations and switching stations is dependent on the application of a robust maintenance regime and the spares strategy for both consumable and major spares (TB 713).

Regarding recent studies for HV equipment, SC A3 has focused on ageing analysis for MO surge arresters (TB 696 (2017)) and equipment such as circuit breakers, disconnector, earthing switches, (TB 725 (2018)). The JWG A3.32/CIRED reported in August 2018 on non-intrusive condition assessment methods of switchgear, that can be applied on HV and MV circuit breakers and switches and stated that they enable to predict the end of life.

At present, SC B4 has mainly focused on availability. Going in that direction, more work is needed in SC B4 on condition monitoring and predictive maintenance for HVDC systems while considering the latest technology improvements. Furthermore, this work will be in line with the work started in SC A3 on ageing and on non-intrusive condition assessment methods for HV equipment.

Condition monitoring requires the measurement of one or more damage indicators during the power converter operation. Condition indicators need to be identified for the power electronics asset. Usual condition indicators for power semiconductor devices are the on-state voltage or resistance (VCEsat/RON), the internal thermal resistance (Rth), and the junction temperature (Tjeq). Health indicators for capacitors in MMCs are the Equivalent Series Resistance (ESR) and capacitance.

Today, there is a lack of information on failure in the field of such components and research is still ongoing to improve current reliability models. Still, based on the current state of the reliability models, diagnosis can be made to estimate their state of heath (SoH) or the root cause of failure upon occurrence of a fault. The diagnostic allows utilities to develop the operation and predictive maintenance strategy adapted to the variable operating conditions and environments of HVDC converters, onshore and offshore converters.
The predictive maintenance strategies should include the economic life expectancy of the component incorporating a depreciation cost.

Scope:

The current state of monitoring, diagnosis for HVDC systems will be studied in this WG. The pertinent health indicators should be identified for the different HVDC components and subsystems. The different condition monitoring approaches which lead to the diagnostics will be compared. Furthermore, in regard to safety, reliability and cost effectiveness of HVDC systems, traditional, preventive and predictive maintenance strategies will be benchmarked.

The WG will work toward identifying and qualifying the indicators to help the decision making of facilities owners to develop/implement optimized station maintenance strategy (i.e. in response to the detected components degradation to decide on the follow-up such as refurbishment, replacement, possible life extension measures in comparison to the maintenance cost and the operation needs). Based on the findings, recommendations with included selected case studies will be prepared.

The working group will perform the following tasks

1. The HVDC subsystems and components
    a. HVDC systems description:
        i. identification of the subsystems and components in the HVDC systems and their functions
        ii. HVDC systems operation modes:
    b. Identification of operating modes that impact the health profile during the lifespan
    c. Identification of the critical equipment prone to failure in the HVDC systems
2. State of the art of condition monitoring for HVDC systems
    a. Health condition indicators of the identified HVDC system equipment to be monitored: ex for MMC, the semiconductor IGBT devices, capacitors sensors, insulation, cables…
    b. The Monitoring methods
        i. Traditional approaches
        ii. HVDC subsystems and components enhanced approached

3. Diagnostics
    a. Definition of the state of health: healthy, damaged, out of service
    b. Estimation of the state of health
    c. Estimation of the root cause failure
4. Predictive maintenance
    a. prioritization the health/damage equipment regarding the impact on the health of the HVDC system
5. Maintenance strategies with economic lifespan:
    a. definition of the different lifespan cost
    b. traditional:
        i. run to failure and replacement or repaired upon failure
        ii. maintenance planned at regular time with possible refurbishment
    c. preventive
        i. maintenance planned at regular time
    d. predictive, maintenance is carried out in response to the observed degradation in component condition
    e. comparison of the maintenance strategies regarding the required tools for monitoring, the return of investment

6. Guidelines of maintenance strategies and business model in regards to safety, reliability and cost effectiveness in HVDC systems

Deliverables:

☒ Technical Brochure and Executive Summary in Electra
☒ Electra Report
☒ Future Connections
☐ CSE
☒ Tutorial
☒ Webinar

Time Schedule: start: August 2020 **Final Report**: September 2022

Approval by Technical Council Chairman: Marcio Szechtman

Date: June 30th, 2020

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.