CIGRE Study committe A3

PROPOSAL FOR THE CREATION OF A NEW WORKING GROUP

JWG A3/D2.52

NAME OF THE CONVENOR
Mantilla Javier (SWITZERLAND)

TITLE
Application of Digital Twin in Switchgear

THE WG APPLIES TO DISTRIBUTION NETWORKS: YES

ENERGY TRANSITION
3 / Digitalization

POTENTIAL BENEFIT OF WG WORK
2 / potential interest from a wide range of stakeholders
4 / state-of-the-art or innovative solutions or directions

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 ongoing transition of power systems is characterized by the deployment of digital technologies across various grid assets. Networks are becoming digitized and automated, incorporating advanced sensors, smart meters, and intelligent devices. This progress in digitalization is enabled through rapid development of hardware, as well as software, with data algorithms and machine learning. Together, the combination of hardware and software establishes the foundation for effectively utilizing digital twin (DT) concepts in electrical networks. Digital twin methodology has indeed been a focus in recent research activities, successfully demonstrated in applications such as manufacturing process virtualization and modeling individual equipment like motors or drives.

PURPOSE / OBJECTIVE / BENEFIT OF THIS WORK :

The concept of a digital twin is interpreted and approached differently across the industry. For some, it may represent a detailed virtual replica of a physical asset, created to monitor and predict performance in real-time. For others, it may serve as a simpler simulation tool that provides insights based on historical data and generalized models. These varying interpretations reflect the range of applications and levels of complexity that digital twins can offer, from basic monitoring to highly predictive, data-driven modeling. Aligning these perspectives within the power industry could unlock greater consistency in development and application.

Despite this, applications of digital twins in the electrical power industry, particularly for switchgear, remain underdeveloped. Manufacturers are increasingly focused on software-driven power solutions through advanced analytics, with a special emphasis on "smart switchgear" equipped with real-time monitoring of various parameters. By simulating a switchgear's behavior, a digital twin provides valuable insights into its operational efficiency, condition monitoring, and potential failure modes. This enables operators and engineers to visualize the asset within a substation, monitor its performance, run what-if scenarios, and make informed decisions for optimal operation and maintenance.

To advance this paradigm, the switchgear lifecycle should be analyzed to identify areas that can benefit from digital twin applications. This includes phases from design and development, manufacturing, operation, and maintenance, to end-of-life, covering both normal and extreme operating conditions. The complete process can be supported by digital twin concepts.

SCOPE :

The scope of work will be divided as follow:

1. Harmonize the understanding and definition of the digital twin concept within our segment of the industry, ensuring all stakeholders share a consistent framework and approach.
2. Review literature on digital twin and related digital technologies used in switchgear in power systems, through condition monitoring, data management, physical and virtual models, machine learning, etc. Consider IEC and CIGRE contributions, with following but non-exclusive list:
a. IEC TC17 (High-voltage switchgear and controlgear): WG 10, WG 11, MT 9
b. IEC TC57 (Power systems management and associated information exchange): WG10, WG13
c. IEC TC 123 (Management of network assets in power systems): WG2
d. ISO/IEC JTC 1/SC 41 (Internet of Things and Digital Twin)
e. CIGRE WGs:
- JWG A2/D2.65 (Transformer Digital Twin – concept and future perspectives)
- D2.52 (Artificial intelligence application and technology in power industry), D2.53 (Technology and applications of internet of things in power systems), C4.64 (Application of real-time digital simulation in power systems),
- C1.43 (Requirements for asset analytics data platforms and tools in electric power systems),
- JWG B3/D2.62 (Life-long Supervision and Management of Substations by use of Sensors, Mobile Devices, Information and Communication Technologies),
- JWG A3.32 (Non-Intrusive Methods For Condition Assessment Of Distribution And Transmission Switchgear)
- JWG A3.43 (Tools for lifecycle management of T&D switchgear based on data from condition monitoring systems)
- WG 13.09 (User Guide For The Application Of Monitoring And Diagnostic Techniques For Switching Equipment For Rated Voltages Of 72.5 kV And Above)
- WG B3.12 (Obtaining Value from On-Line Substation Condition Monitoring).

f. CIGRE Session 2022 papers:
- A3-PS3 (Digitalisation of T&D equipment),
- D1-PS3 (Simulation tools partnered with measurement techniques),
- B3-PS3 (Integration of intelligence on substations).

g. CIGRE Session 2024 papers:
- A3-PS3 (Maintaining and management T&D assets),
- B3-PS2 (Return on operational experiences for substation management),
- D1-PS1 (Testing, monitoring and diagnostics).

h. IEEE and NEMA publications
i. Utilitites works and publications on DT
j. CIGRE SCs D2 and B3 works on DT
k. Others
3. Identify and analyse the existing digital twins platforms/tools/languages most commonly used for different applications highlighting their different characteristics, their interoperability and standards followed (e.g. IEC 61850, CIM, BIM)
4. Survey on use cases and types of digital twin concepts. Evaluate the benefits and reliability of their application in the switchgear lifecycle. Identify implementation barriers, such as cost and time requirements versus added value.
5. Analyze the management of data availability and sources, data quality, and modelling across different functions of various network switchgear assets. Develop recommendations for the relevant standardization of data management, modelling, and machine learning techniques to support the deployment of digital twins in switchgear.
6. Identify gaps between virtual and physical models. Investigate how and under which conditions these models can be enhanced and validated, for example, with the help of advanced simulation techniques, artificial intelligence, and machine learning algorithms.
7. Propose methodologies for the utilization and selection of digital twin concepts for new and existing switchgear, and explore their potential leverage within IoT.
8. Analyze opportunities for implementing switchgear digital twins within a system-based approach to substation software automation. This may include potential scalability to larger network segments, enabling forecasting and simulation applications for future network states.
9. Study the impact/scope/goal of digital twins in digital product passports (DPP) and similar policy-makers initiatives.
10. Study the gaps that digital twin integration can address in switchgear and power systems.
11. Evaluate the cybersecurity aspects of digital twins, potential threats, and mitigation strategies in the face of cyber-attacks or system failures.
12. Study the relationship between digital twins and political policies in Europe and worldwide. Outline key considerations for future policies, suggesting areas to regulate or leave unregulated, and assess the potential impact of these choices on power systems and society.
13. Cooperate and synchronize with the activity of the WG B5.86 "Protection Automation and Control System interfaced asset management and condition monitoring using innovative technologies"

DELIVERABLES AND EVENTS

Deliverables Types
Annual progress and activity report to Study Committee
Electra report
Meeting
Technical Brochure and Executive Summary in Electra
Tutorial
Webinar

Deliverables schedule

Meeting	Q1	2025	Kickoff meeting

Time schedule

Q4	2028	Publication

APPROVAL BY TECHNICAL COUNCIL CHAIRMAN:
Rannveig S. J. Løken
February 03rd, 2025