

## CIGRE Study committee D2

### PROPOSAL FOR THE CREATION OF A NEW WORKING GROUP

#### WG D2.67

##### NAME OF THE CONVENOR

Pu Tianjiao (CHINA)

##### TITLE

Power Embodied Intelligence Technology and Application

#### 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
- 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

##### 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-of-the-art technological advances

##### SUSTAINABLE DEVELOPMENT GOAL

9 / Industry, innovation and infrastructure

#### BACKGROUND :

Power Embodied Intelligence (PEI) implements physical interaction with the power system, including facilities (substation, transmission line, etc.), by using **embodied artificial intelligence** (E-AI) agents. By embedding AI algorithms into robotic systems, drones, and sensor networks, PEI leverages real-time environmental perception, multimodal data fusion, and dynamic control to enhance grid resilience, operational efficiency, and safety. This technology addresses critical challenges in power transmission, distribution, operation and maintenance by combining physical embodiment (e.g., humanoid robots, inspection robots, UAVs) with E-AI agent. The key advantages include:

- **Multimodal data fusion:** Embodied intelligence agents analyze multimodal data (g., LiDAR, thermal imaging, electrical parameters) to detect faults, predict failures, and optimize grid operations.
- **Real-time Responsiveness:** On-device processing ensures sub-second decision-making for critical tasks like fault isolation or load balancing.
- **Autonomy:** Operates in remote or hazardous environments (e.g., offshore wind farms, underground cables) without reliance on cloud connectivity.
- **Adaptability:** Lightweight AI models enable rapid deployment across diverse hardware, from robotic arms to micro-sensors.

PEI aligns with global trends in smart grid modernization and is poised to reinforce CIGRE's research topics, bridging gaps between digital twins, robotics, and power systems. This technology will be increasingly utilized within the scope of most CIGRE's study Committees. The new WG will focus on common technology developments, and other related SCs will focus on PEI under their own scopes.

#### PURPOSE / OBJECTIVE / BENEFIT OF THIS WORK :

The purpose of the Working Group (WG) is to establish a reference document on embodied intelligence technology and application for power industry, achieving consensus on cutting-edge technologies among power industry enterprises and institutions (power utilities, generation companies, independent system operators, load aggregators, etc.), research institutions, academia as well as equipment and system vendors, promoting conceptual consistency and technology recognition and adoption, exploring and identifying practical application scenarios and key technologies, formulating , laying the foundation for large-scale implementation for power utilities.

**SCOPE :**

The working group will cover:

- 1) State of the art of Embodied Intelligence in Power Systems  
Survey global advancements in E-AI applications for power grids, including robotic maintenance, autonomous drones, and adaptive sensor networks. Analyze gaps in scalability and interoperability.
- 2) Architecture Design for Power System Embodied Intelligence  
Define hierarchical frameworks for embodied Intelligence systems, integrating edge computing, Cloud-Edge coordination and decentralized control,including the complement/definition of standards or norms applicable in the field of the industrial sector, covering data and ML structure standardization, architecture design, security, safety, human-machine level of decision-making, product certification of PEIs. Address power supply, security for AI, and fail-safe mechanisms for field-deployed agents.
- 3) Key technologies of Embodied AI  
Develop technologies for multi-modal sensor fusion, coordination between high level cognitive models and low level control systems, advanced motion control for robotics, simulation frameworks for large-scale embodied intelligence models, and resilience against adversarial attacks and environmental noise.
- 4) Deployment and Integration Challenges  
Standardize interfaces for cloud-robot collaboration, data sharing, and over-the-air model updates. Investigate energy-efficient hardware (e.g., low-power GPUs, modular actuators) for sustained field operations. Study on ethics of Artificial Intelligence.
- 5) Typical Applications  
Robotic Inspection and Maintenance: Deploy swarm robots with context-aware and group learning to optimize time of reparation, data collection or fault detection for transmission line repair, substation monitoring, underground cable fault detection and so on.  
UAV Swarm for Grid Surveillance: Enable real-time aerial mapping of wildfire risks , vegetation encroachment, and ice buildup on power lines.  
Self-Regulating Microgrids: Use embodied agents to dynamically balance distributed energy resources (DERs) and stabilize grid frequency.  
Human-Robot Collaboration: Develop assistive exoskeletons and cobots for field technicians in high-risk environments such as Aquatic Robotic Inspection for hydroelectric power plants.  
Power system equipment condition monitoring: Robots equipped with visual, thermal, acoustic, electromagnetic, and UHF sensors autonomously detect anomalies such as overheating, insulation degradation, and partial discharge (PD) in power equipment, enabling real-time analysis, early fault detection.

**DELIVERABLES AND EVENTS**

**Deliverables Types**

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

**Time schedule**

- Q4 2025 Recruit members

- |    |      |                        |
|----|------|------------------------|
| Q2 | 2026 | Develop work plan      |
| Q3 | 2027 | Draft TB for SC Review |
| Q4 | 2027 | Final TB               |
| Q1 | 2028 | Webinar                |
| Q3 | 2028 | Tutorial               |

**APPROVAL BY TECHNICAL COUNCIL CHAIRMAN:**

Rannveig S. J. Løken  
October 17th, 2025