CIGRE Study committe C1

PROPOSAL FOR THE CREATION OF A NEW WORKING GROUP

WG C1.60

NAME OF THE CONVENOR
Fan Yue (CHINA)

TITLE
Multi-Domain Co-Optimization of Flexibility Resources for High-RES Power Systems

THE WG APPLIES TO DISTRIBUTION NETWORKS: YES

ENERGY TRANSITION
1 / Storage
2 / Hydrogen
5 / Grids and Flexibility
7 / Consumers, Prosumers and Electrical Vehicles
8 / Sector Integration

POTENTIAL BENEFIT OF WG WORK
1 / commercial, business, social, economic benefits
3 / likely to contribute to new or revised industry standards

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
3 / Focus of the environment and sustainability (in case the WG shows a direct contribution to at least one SDG)

SUSTAINABLE DEVELOPMENT GOAL
7 / Affordable and clean energy
9 / Industry, innovation and infrastructure

BACKGROUND :

The structural transformation of power systems—driven by the increasing share of variable renewable energy sources (VREs) such as wind and solar PV—poses fundamental challenges to system planning, operation, and stability. The decline in dispatchable synchronous generation has weakened traditional mechanisms for frequency support, ramping, and system balancing.

Flexibility is now a key enabling capability for high-RES systems. Multiple flexibility resources—including energy storage (electrochemical, mechanical, and thermal), demand-side response, flexible generation, virtual power plants, and emerging hydrogen-based systems—can support system balancing. However, their diverse dynamic characteristics, integration pathways, and value stacking mechanisms require coordinated planning and system-level optimization, which is currently underdeveloped in existing international work.

While past CIGRE Working Groups (e.g., C1.39, C1.44, C1.43, C1/C6.42) have explored uncertainty-aware planning, DER-based flexibility, and hybrid energy systems, none has developed a unified framework for multi-modal flexibility co-optimization at the system level, especially under operational, economic, and physical constraints in high-RES power systems.

PURPOSE / OBJECTIVE / BENEFIT OF THIS WORK :

The purpose of this Working Group is to advance the state-of-the-art in power system planning by developing a technically rigorous and practically applicable framework for the system-level co-optimization of flexibility resources in high-renewable power systems undergoing structural transformation.

The key objective is to create a unified methodology for analyzing, modelling, and optimizing the deployment and operation of flexibility resources, such as battery storage, hydrogen energy systems, responsive loads, thermal storage, and hybrid generation configurations—across multiple timescales and grid layers.

This WG will deliver engineering insights into system performance implications, control requirements, and the economic and reliability trade-offs between flexibility portfolios. It will also generate actionable planning tools and modelling guidelines for utilities, regulators, and system operators.

The expected benefits include:

- Supporting carbon-neutral transitions through optimized flexibility integration;
- Providing technical foundations for future flexibility standards and regulatory frameworks;
- Enabling robust planning under uncertainty and diverse system contexts;
- Facilitating dynamic modelling of hydrogen, long-duration storage, and demand response resources.

Furthermore, this WG will develop a structured framework to compare different flexibility resources in terms of performance and cost, from the perspective of an unbiased grid operator. Flexibility options will be grouped into comparable service clusters, enabling technology-neutral procurement decisions. This ensures practical applicability of the WG outcomes to market and system planning processes.

SCOPE :

This Working Group will undertake a comprehensive technical investigation of the coordinated planning and system-level co-optimization of diverse flexibility resources. The scope includes:

Develop a multi-timescale power and energy balancing methodology—spanning sub-hourly, hourly, daily, and seasonal intervals under varying levels of VRE integration—that incorporates uncertainties in generation and demand, including those arising from weather forecasts, net-load variability, and outage conditions. This approach aims to identify flexibility gaps and critical stress scenarios, ultimately ensuring supply adequacy and maximizing renewable energy utilization.

Formulate detailed technical models for various flexibility resources, including electrochemical storage (e.g., Li-ion, flow batteries), mechanical storage (e.g., pumped hydro, CAES), thermal storage (e.g., heat-based storage, power-to-heat), hydrogen-based energy systems (electrolysis and reconversion), demand-side flexibility (e.g., load shifting, curtailable loads), and flexible thermal generation. Each model will characterize dynamic behavior, operational constraints, intertemporal trade-offs, degradation effects, and coupling interfaces.

Develop a system-level co-optimization framework to determine the optimal mix, sizing, and dispatch of flexibility resources. The optimization will address multiple objectives such as minimizing total system cost, reducing emissions, enhancing adequacy, and maintaining stability. Both centralized and decentralized coordination schemes (e.g., aggregator-based or TSO-led) will be considered and evaluated.

Analyze the impact of flexibility portfolios on system operations, particularly in terms of frequency control, inertia provision, ramping capabilities, and voltage/reactive power support. Specific attention will be paid to the interaction between converter-based resources and legacy synchronous machines, and the dynamic implications of grid-forming inverters and hydrogen reconversion units.

Propose a performance-cost comparison mechanism by grouping flexibility options into service-equivalent clusters, and define evaluation metrics through a structured methodology to compare heterogeneous flexibility options from a procurement-neutral perspective. This includes:

- Grouping flexibility technologies into comparable service clusters;
- Defining metrics for response time, duration, efficiency, degradation, and cost per unit of service;
- Developing guidelines for system operators to evaluate and procure portfolios in a technology-agnostic manner.

Representative case studies will be conducted using integrated simulation platforms combining steady-state optimization, dynamic simulation, and probabilistic scenario modeling. These case studies will cover different system topologies (meshed vs. radial), load profiles, and flexibility resource availabilities. Extreme conditions such as long-duration VRE droughts or N-1/N-2 contingencies will be included to test the robustness of proposed solutions.

Provide practical recommendations and planning guidelines. These will include flexibility evaluation metrics, resource stacking principles, standard modeling templates, and simplified tools suitable for implementation by system planners, regulators, and stakeholders in various power system contexts.

Remarks:

This topic is highly relevant to both system operators and flexibility providers, and it wil complement the ongoing WG C1.54 which focuses on assessing and planning the "needs" of reserve and flexibility, while the new WG will address the "means" of flexibility to cover such needs.

The WG will refer to WG C1.54 results for demand-side parameters and reserve assessment methodologies. This ensures consistency and avoids duplication of effort.

This WG will align with WGs C6-C2.34 and C6.35 once they are finalised.

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

Q4	2025	recruiting members
Q1	2026	Workplan
Q3	2027	TB draft for SC commenting
Q4	2027	Final TB
Q1	2028	Tutorial / Webinar

APPROVAL BY TECHNICAL COUNCIL CHAIRMAN:
Rannveig S. J. Loken
December 16th, 2025