CIGRE Study committe C1

PROPOSAL FOR THE CREATION OF A NEW WORKING GROUP

JWG C1/D2.56

NAME OF THE CONVENOR
Yamaki Koichiro (JAPAN)

TITLE
Electrical-Cyber Integration to meet Net Zero Goal by support of Cloud Infrastructure

THE WG APPLIES TO DISTRIBUTION NETWORKS: **YES**

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

POTENTIAL BENEFIT OF WG WORK
1 / commercial, business, social, economic benefits
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-ofthe-art technological advances
3 / Focus of 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

SUSTAINABLE DEVELOPMENT GOAL
9 / Industry, innovation and infrastructure

BACKGROUND :

The rise of generative AI and the growing need for digital infrastructure have led to a rapid increase in large-scale data centers, which consume vast amounts of electricity. Data centers typically require constant power to maintain their operations, making them less compatible with renewable energy sources like solar and wind, which generate power intermittently. Despite this, market trends and corporate sustainability goals drive data centers to rely on renewable energy.

CIGRE has introduced an innovative approach in ELECTRA: Watts & Bits: How Power Grids and Cloud Computing Are Working Together to Implement “Utility 3.0” Through Electro-Cyber Integration (N°335 August 2024).

This mismatch between constant demand and variable supply creates challenges for grid operators. Without innovative solutions, integrating data centers into the energy system could strain grid stability and limit the use of renewable energy. The MESH concept offers a potential solution by enabling data centers to shift their energy-intensive tasks to times and locations where renewable energy is most abundant, helping to balance supply and demand. AI, despite its high-power demand, is also expected to assist TSOs in addressing grid management challenges from multiple perspectives.

This WG will focus on assessing the potential of demand response by data centers to respond to flexibility needs by the systems (which can be related to renewables, or price signals, or imbalances,...). In particular, it will be analysed the MESH concept and its benefits in managing the complex interaction between large-scale digital infrastructure and renewable energy. Additionally, it will provide practical insights for TSOs on how to design Grid Codes that accommodate data center energy demand while supporting the transition to a greener energy system.

Purpose/Objective/Benefit of this work:

The purpose of this WG is to develop strategies and guidelines that help TSOs manage the integration of data centers into the power grid. By leveraging the MESH framework and other AI-driven solutions, the WG aims to transform data centers into flexible, grid-friendly assets that can dynamically adjust their energy use based on renewable energy availability.

Key benefits include:

- For TSOs: Practical guidelines on how to design Grid Codes that encourage data centers to optimize their energy consumption, supporting grid stability while promoting renewable energy integration.
- For Data Center Operators: Recommendations on how to realize ‘Cognitive Foundation’ by using AI and cloud computing to manage energy use efficiently, reduce operational costs, and align their energy consumption with the availability of renewable energy.
- For the Energy Sector: Insights into how data centers can evolve from being constant, passive loads to active participants in a dynamic energy system, contributing to the decarbonization of the power sector.

The WG’s findings will ultimately provide a foundation for more flexible and sustainable energy management practices in an increasingly digital world.

PURPOSE / OBJECTIVE / BENEFIT OF THIS WORK :

The rapid digital transformation, such as the increasing development of large-scale data centers driven by the growing demand for generative AI and digital infrastructure, presents significant challenges for power grids. Unlike other consumers, data centers typically have constant power demand, making them poorly suited for integration with variable renewable energy sources like solar and wind.

On the other hand, the energy sector has been requiring the followings:

- Meet Net Zero Goals
- Handle Accelerating Load Growth
- Support Distribution-Connected Energy Resource Proliferation
- Overcome Infrastructure Challenges
- Adapt To Climate Change

Data center operators are increasingly interested in powering their operations with renewable energy, adding another layer of complexity.

This Working Group (WG) will explore how to address these challenges through innovative solutions such as the Machine-learning Energy System Holistic (MESH) concept. MESH integrates AI-driven workload management with cloud computing, enabling data centers to dynamically shift their energy use to align with periods of high renewable energy availability. The WG will focus on developing strategies such as temporal and geographical workload shifting in accordance with dynamic nodal pricing or other pricing/carbon intensity signals from TSOs. Additionally, the WG will investigate the roles of various players in the data center supply chain, including data center owners, data managers, and manufacturers, analyzing their business models and market dynamics.

The ultimate goal is to provide TSOs with actionable insights for designing Grid Codes that facilitate the integration of data centers into the energy system while promoting grid stability and renewable energy utilization.

Deliverables:

- A detailed report on the challenges and opportunities presented by the increasing power demand of data centers, particularly in the context of their integration with renewable energy sources.
- Case studies demonstrating how cloud computing and AI can optimize data center energy consumption by shifting workloads to times and locations where renewable energy is available and grid conditions are favorable.
- Guidelines for TSOs to develop Grid Codes that account for the constant energy demand of data centers while encouraging the use of renewable energy and ensuring grid reliability.
- Assessment of innovative technologies to counteract the surge in data center energy demand.
- Identification of key players in the data center supply chain, their business models, and their implications for grid integration.
- Recommendations on how data centers can transition from passive, constant energy loads to flexible, grid-friendly assets through intelligent workload management and cloud computing integration.
- Summary of grid challenges associated with the expansion of data centers beyond supply-demand imbalances and congestion, including power quality degradation and other operational issues, supported by real-world case studies.
- Good examples of activities by TSO and DSO, regulator, or government to encourage data centers installation location shift and demand shift.

Proposed Time Schedule:

- Year 1:
  - **Collection of Case Studies on Power Demand Growth**: Investigate scenarios and examples of the growing power demand forecast from data centers.
  - **Classification of Data Center Workflows**: Categorize different data center workflows based on whether or not they can accommodate demand shifting. Identify applications that can shift workloads (e.g., non-real-time AI training) versus those that cannot (e.g., real-time processing or latency-sensitive tasks).
  - **Research on Resources for Demand Shifting**: Investigate specific resources that can support energy demand shifting in data centers, including workflow adjustments, cooling systems, and backup power solutions.
  - **Analysis of Data Center Supply Chain**: Identify the key players in the data center sector, their business models, and how their market positions impact energy demand and grid operations.
  - **Review of Grid Challenges Beyond Supply-Demand Imbalances**: Investigate issues such as power quality degradation and infrastructure constraints related to data center integration.
- Year 2:
  - **Development of Use Cases**: Create detailed use cases that demonstrate how TSOs can utilize data centers' dispatchable capabilities. These cases will explore the practical ways in which data centers can serve as flexible grid assets, helping balance power supply and demand and alleviating grid congestion through workload shifting and optimized energy use.
  - **Final Report**: Prepare and finalize the comprehensive report, including practical guidelines for Grid Code design and recommendations on leveraging AI and cloud platforms for demand management in data centers. These guidelines will focus on helping TSOs maximize the dispatchable capabilities of data centers.

SCOPE :

The WG will focus on the following key area:

- **Constant Power Demand of Data Centers**: Examining how the steady energy needs of data centers affect grid operations and identifying ways to make data centers more flexible through AI-driven workload management. Special attention will be given to the mismatch between constant data center demand and the variable output of renewable energy sources.
- **MESH and Workload Shifting**: Developing and promoting the MESH concept as a solution for aligning data center energy use with renewable energy availability. The WG will create detailed use cases that demonstrate how cloud computing can optimize energy consumption through intelligent workload shifting across time and geography.
- **Grid Code Design for Data Centers**: Providing practical recommendations for TSOs on how to design/adjust Grid Codes that facilitate the integration of large data centers while maintaining grid stability/reliability and maximizing the use of renewable energy.
- **AI and Cloud Integration**: Exploring how cloud-based platforms and AI technologies can be used to optimize the energy consumption of data centers, ensuring that they become flexible, grid-supporting assets rather than constant energy loads.

Remarks:

This WG will focus exclusively on providing insights for TSOs and data center operators, without direct involvement from renewable energy experts or policymakers. The goal is to develop technically sound and practically implementable recommendations applicable in various regulatory and operational environments.

By promoting the MESH concept and offering practical strategies for integrating data centers into the energy grid, the WG aims to contribute to a more flexible and sustainable digital infrastructure. The final report will provide valuable guidance for TSOs in designing Grid Codes and offer data center operators concrete solutions for aligning their energy use with renewable energy generation.

DELIVERABLES AND EVENTS

Deliverables Types

Annual progress and activity report to Study Committee
CSE
Technical Brochure and Executive Summary in Electra
Tutorial

Time schedule

Q3	2025	Recruit members
Q3	2025	Develop final workplan
Q4	2026	Draft TB for Study Committee review
Q1	2027	Final TB
Q1	2027	Tutorial / Webinar

APPROVAL BY TECHNICAL COUNCIL CHAIRMAN:

Rannveig S. J. Løken
July 16th, 2025