AINETUS – AI for safety-critical NEtwork infrastrUctureS

LF Energy Technical Advisory Council (TAC)

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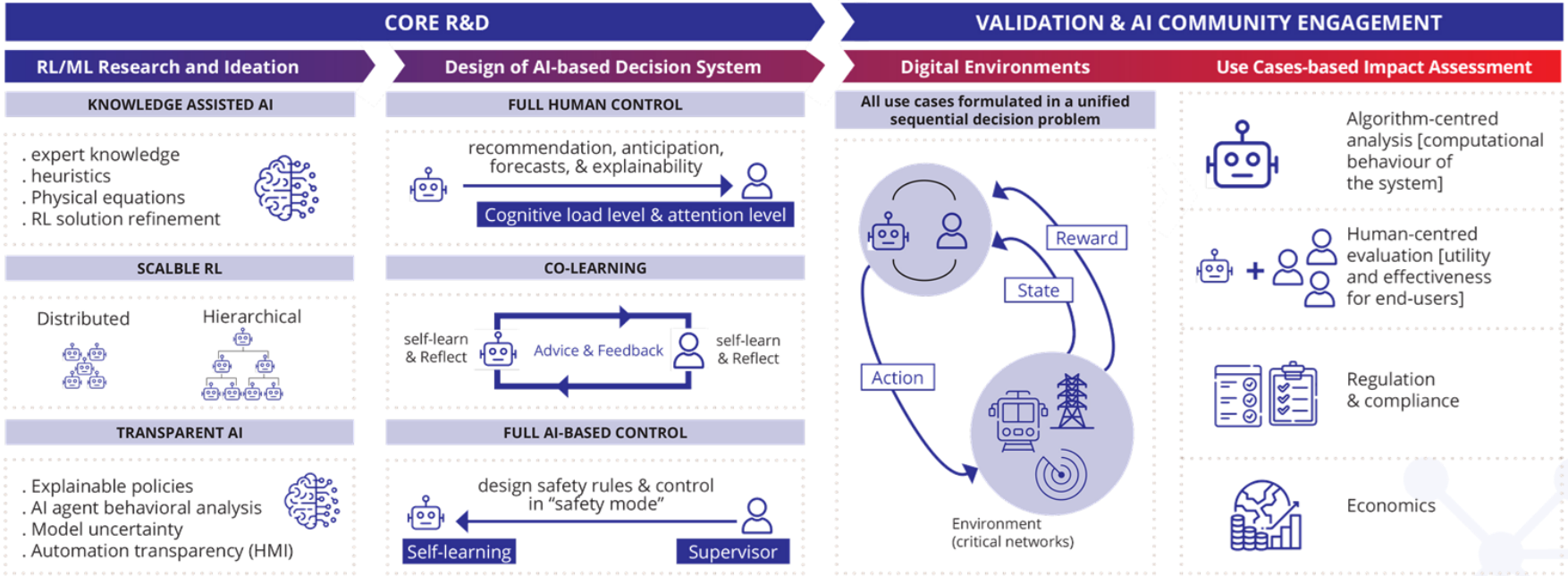
Why AI assistants for critical infrastructures?

- Critical infrastructures (power grids, rail, air traffic, water) are becoming more complex, demanding faster and more sophisticated decisions
- Humans remain accountable, but **AI is increasingly essential for decision support, turning large volumes of data into rapid, context-aware recommendations**
- Traditional control room tools enable robust physics-based decisions, but can be too slow for real-time actions (e.g., topology optimization) and struggle with partial observability and risk modelling
- Control rooms are a fragmented work environment with multi-screen applications, and increasing human cognitive load

AI4REALNET in a nutshell

GOALS

- ❑ Develop the next generation of decision-making methods powered by supervised and reinforcement learning, which aim at trustworthiness in AI-assisted human control, human-AI co-learning, and autonomous AI
- ❑ Boost the development and validation of novel AI algorithms via 3 existing open-source AI-friendly digital environments



Prespective paper

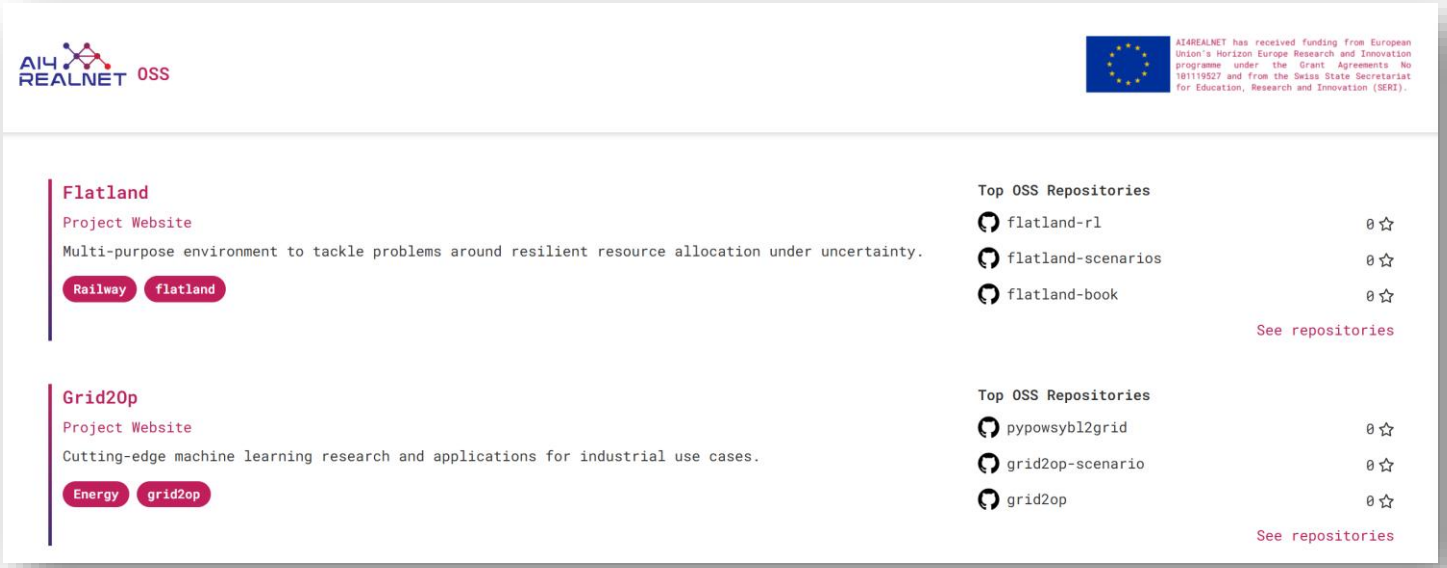
Project information and partners

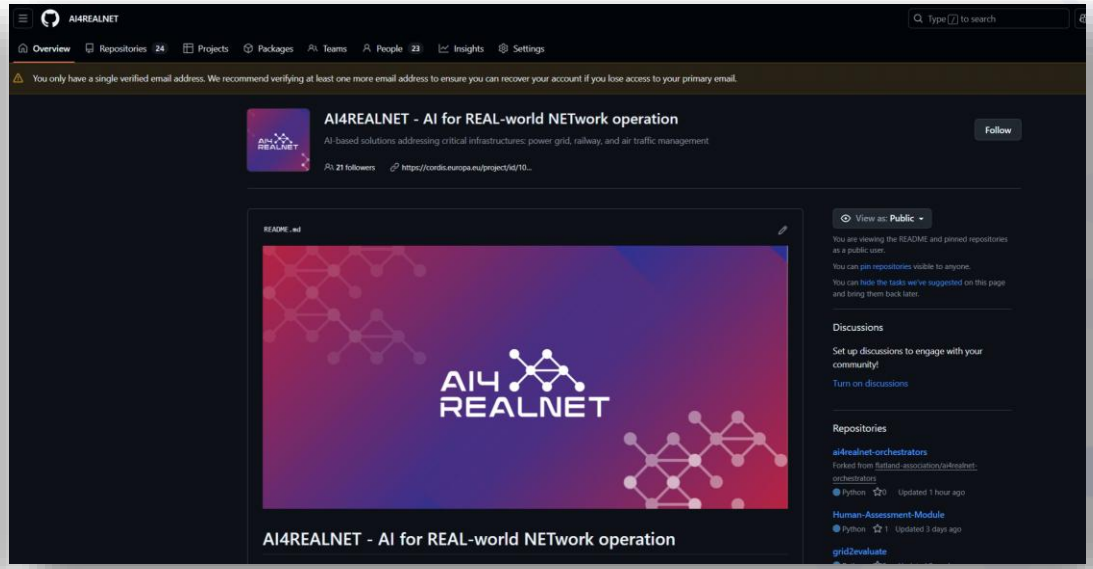
AI4REALNET – AI for REAL-world NETwork operation

- Oct/2023 – Mar/2027
- **Type of action:** Research and Innovation Action (RIA)
- **Budget:** € 3 999 976,25
- **Project coordination:** Ricardo Bessa (INESC TEC)
- **Project officer:** Stefano Foglietta (HaDEA)

Open-source software (GitHub)

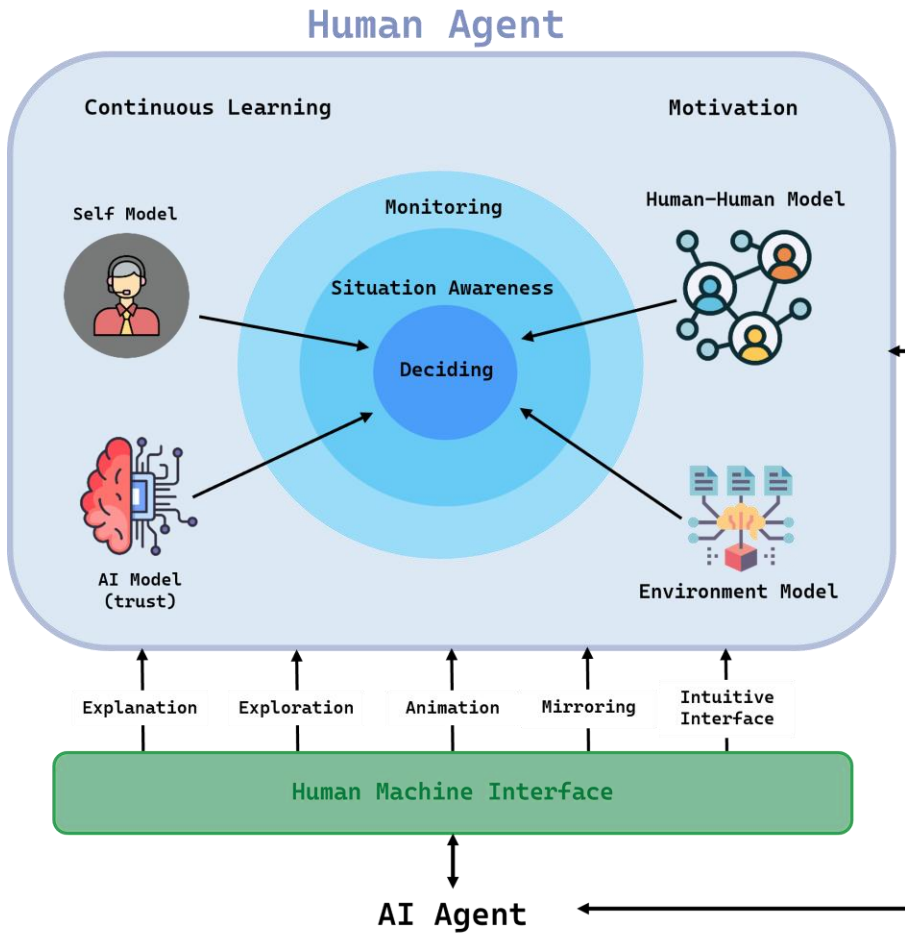
All results will be released in open-source (GitHub page already with several OSS results)





GitHub

Conceptual framework for human-AI interaction



AI-based decision system

gymnasium

Interactive AI

KPIs | Scenario Generation | Baselines

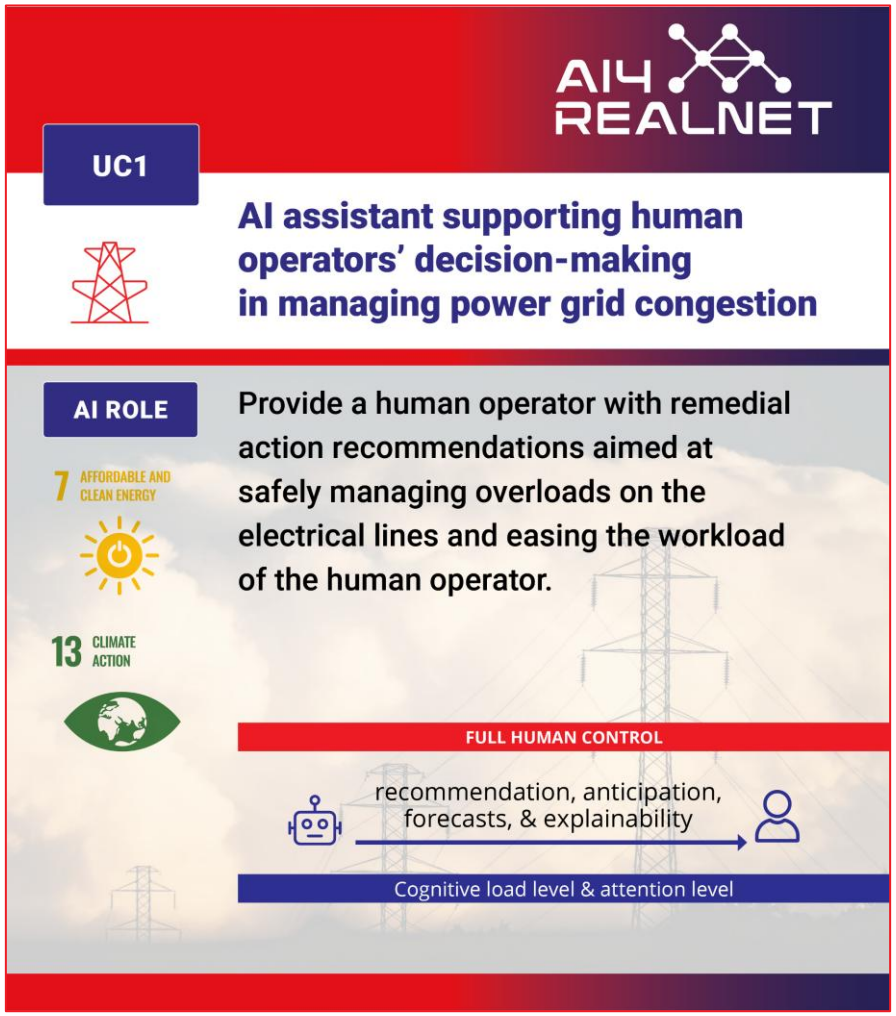
Network Simulator

Contributing to...

LFENERGY grid2op

Framework

Use cases


AI4 REALNET
UC1
AI assistant supporting human operators' decision-making in managing power grid congestion
AI ROLE
Provide a human operator with remedial action recommendations aimed at safely managing overloads on the electrical lines and easing the workload of the human operator.
7 AFFORDABLE AND CLEAN ENERGY
13 CLIMATE ACTION
FULL HUMAN CONTROL
recommendation, anticipation, forecasts, & explainability
Cognitive load level & attention level


AI4 REALNET
UC2
Sim2Real, transfer AI-assistant from simulation to real-world operation
AI ROLE
Provide a human operator with remedial action recommendations, considering a transfer from training (digital) to real-world environments.
7 AFFORDABLE AND CLEAN ENERGY
13 CLIMATE ACTION
FULL HUMAN CONTROL
recommendation, anticipation, forecasts, & explainability
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AINETUS platform

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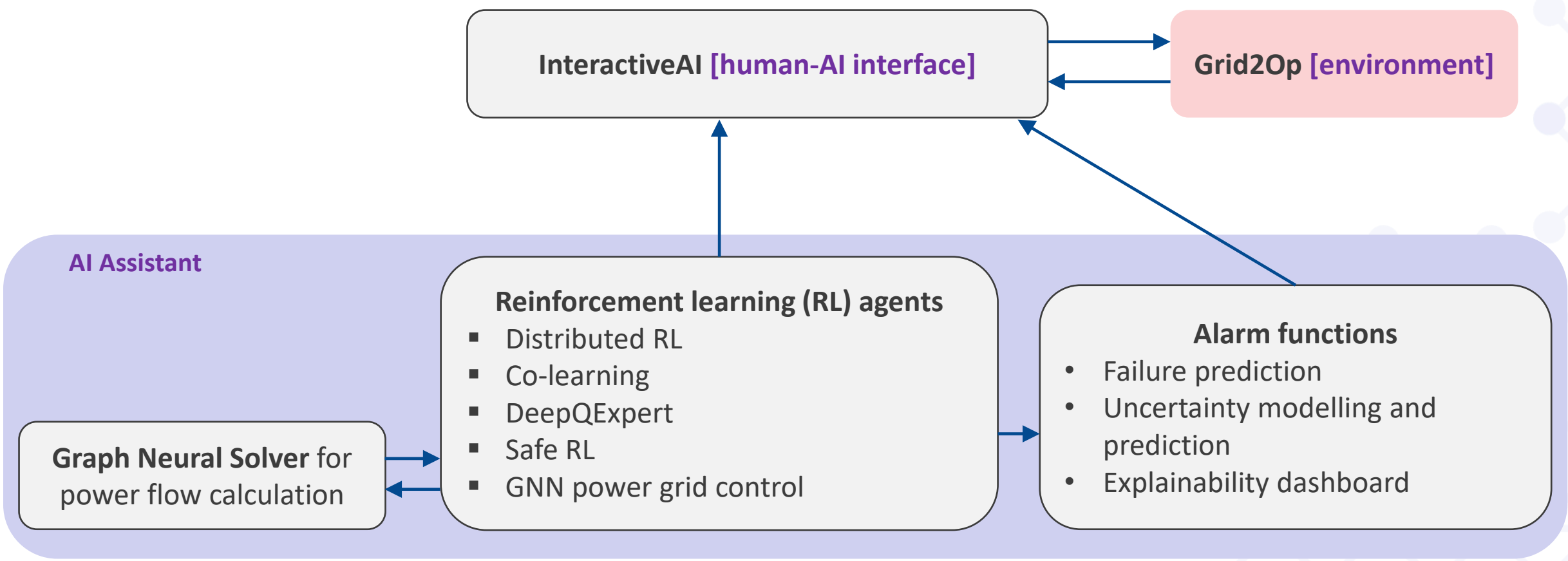
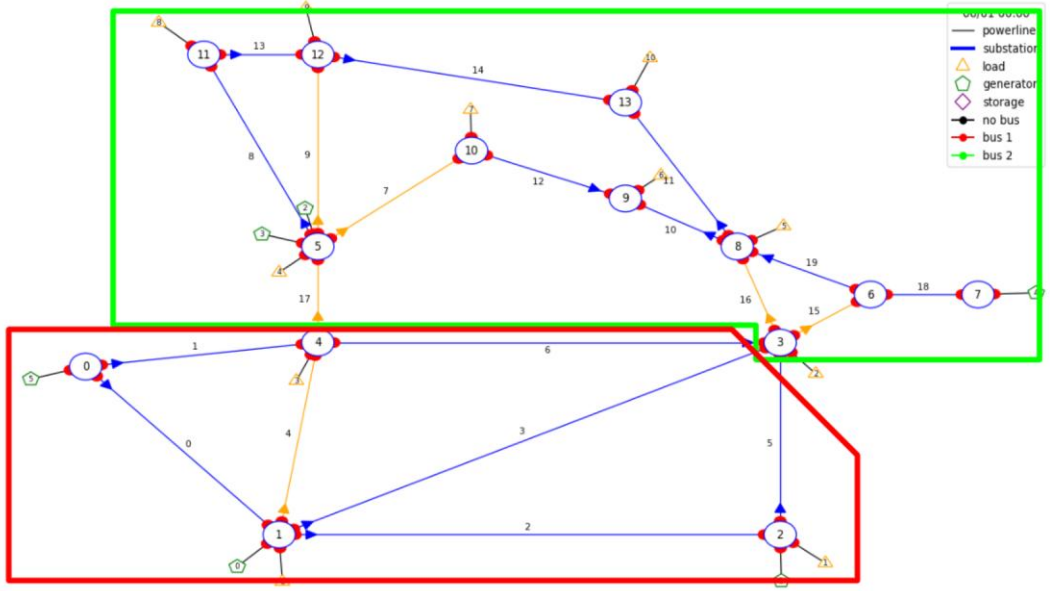
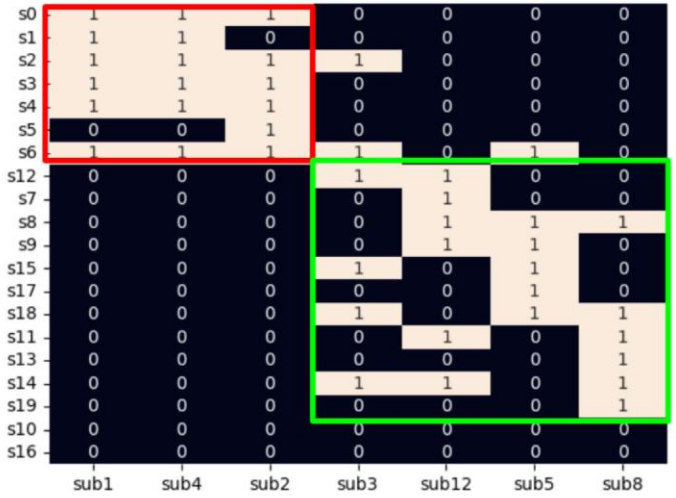


OSS highlight 1: Distributed reinforcement learning

GOAL: Divide into subproblems that can lead to distinct learning processes with less computational and data requirements



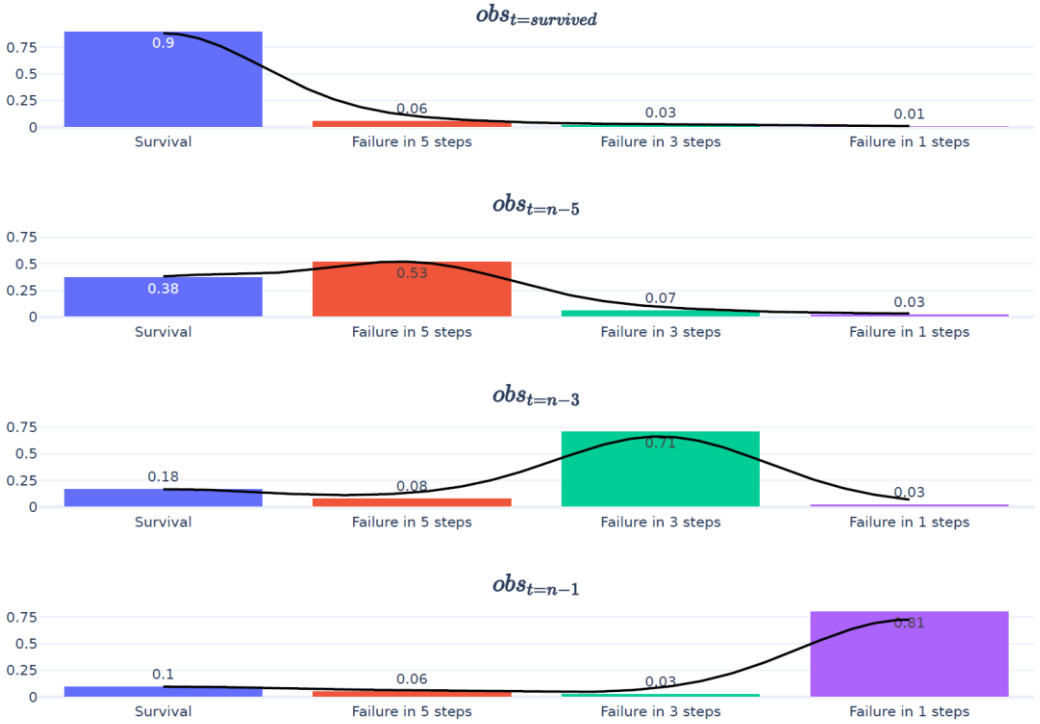


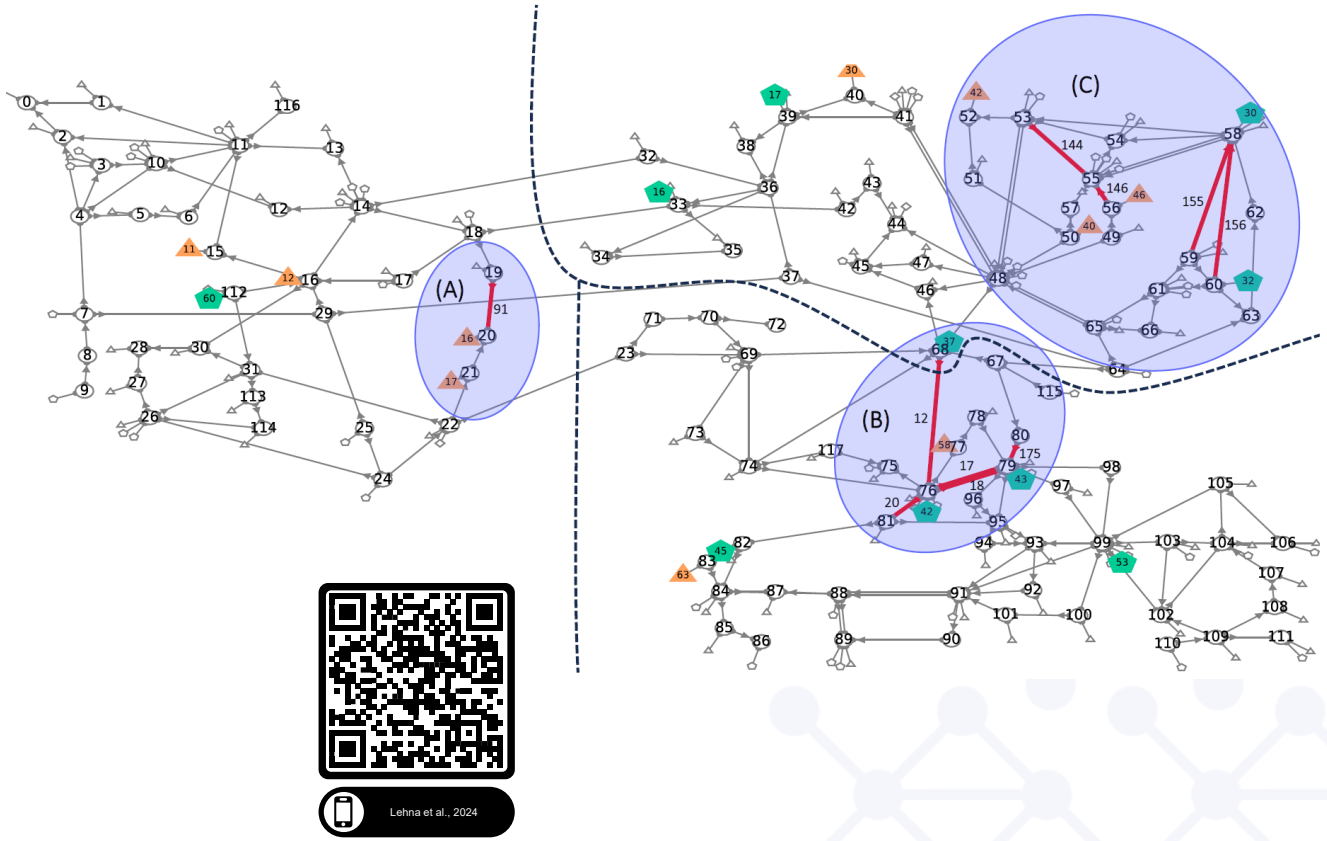
Highly correlated state-action pairs are grouped together to create simpler

Losapio et al, 2024

OSS highlight 2: Predicting AI agent failure

GOAL: prediction approach to detect AI agent failures beforehand





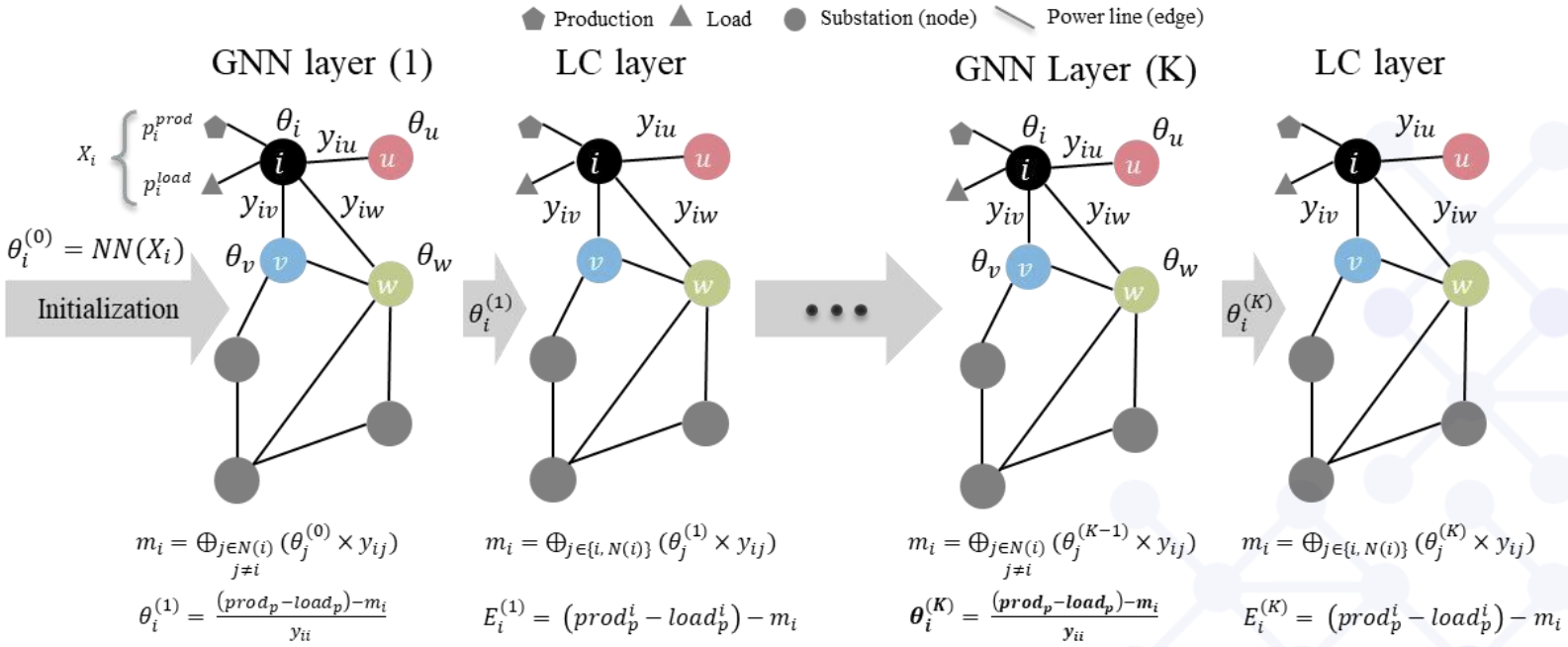
Lehna et al., 2024

OSS highlight 3: Graph neural solver

GOAL: ML assisted (informed) by physics knowledge for compliance with physical constraints imposed in a power grid that enables the prediction of active powers at power lines from the injections in the substations

Compliance with physics laws by integrating the local conservation as the optimization criteria (non-supervised learning)

$$p_i^{prod} - p_i^{load} = (\theta_i \times y_{ii}) + \underbrace{(\theta_u \times y_{iu})}_{\text{message from node } u} + \underbrace{(\theta_v \times y_{iv})}_{\text{message from node } v} + \underbrace{(\theta_w \times y_{iw})}_{\text{message from node } w}$$



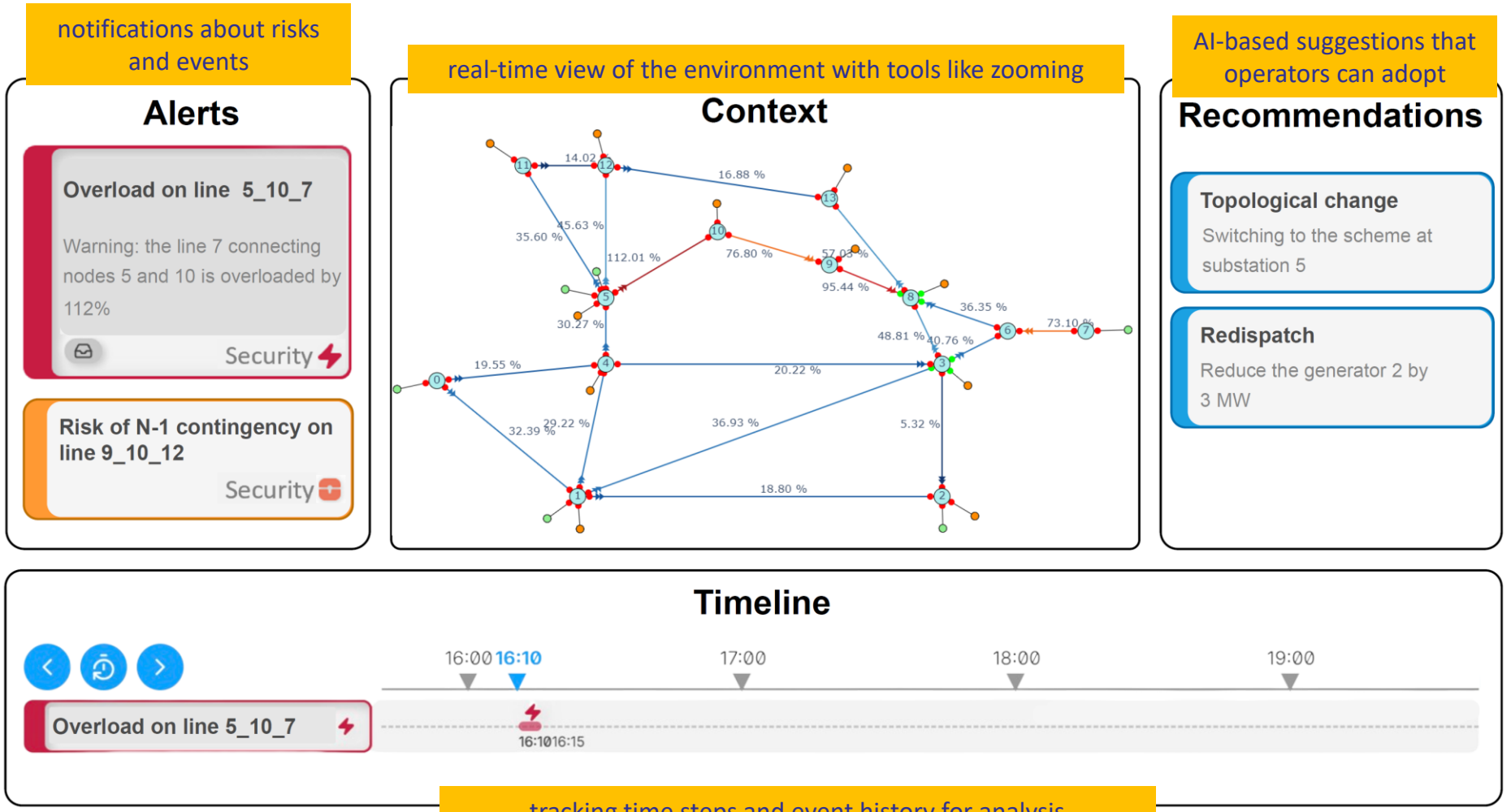
OSS highlight 4: Interactive AI

GOAL: Experimentation of bi-directional virtual assistants for joint decision-making

notifications about risks and events

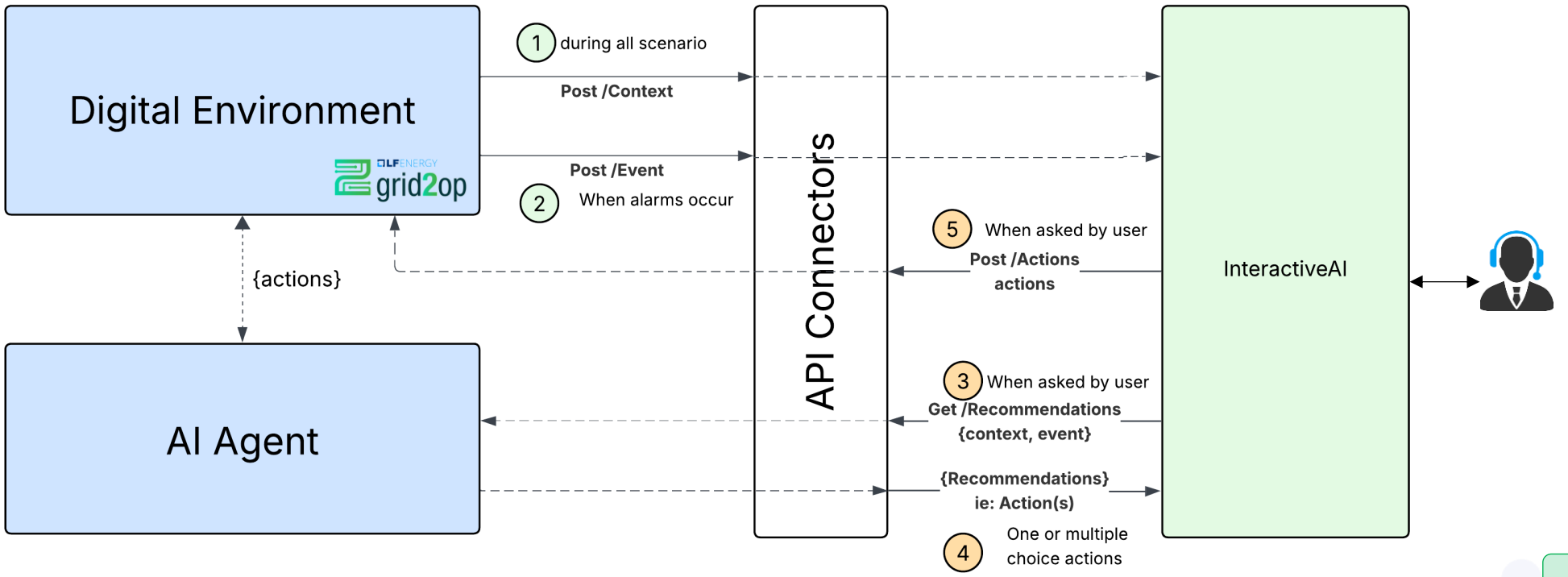
real-time view of the environment with tools like zooming

AI-based suggestions that operators can adopt



tracking time steps and event history for analysis

AINETUS interactions

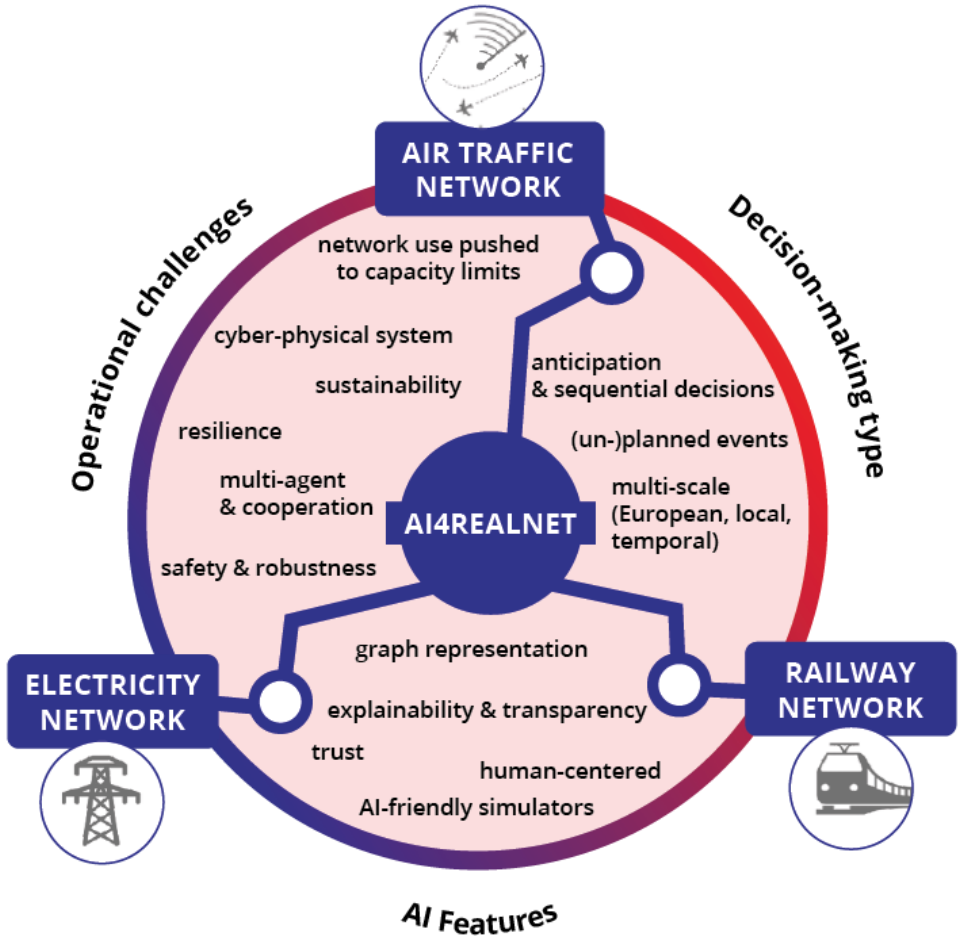


Release#1

Release#2

Short demo

Cross-sector dimension



Cross-sector example: railway

FLATLAND

Flatland input instance.
Graph weights set to **1** at the beginning

Run PP w/ input graph weights

Proposed solution (PP)

Differentiable loss calculation between the 2 solutions

Expert (optimal) solution

Back-propagate loss to update the graph **edge weights**, making PP paths more similar to optimal.

Set **updated weights** for PP

Use **Conflict Based Search** (CBS) to generate optimal paths

outside AINETUS (but relevant for future cross-sector collaborations)

Why LF Energy?

- Opportunity for collaborative improvement of an end-to-end stack for AI assistants (algorithms → HMI)
- Synergies with other LF Energy projects: Grid2Op and OperatorFabric
- Encourage co-creation with TSOs, DSOs, and vendors
- Increase awareness for the development and human-in-the-loop testing of AI solutions aligned with the EU AI Act
- Facilitating continuous improvement of RL agents & HMI (towards agentic AI)
- Open-source to accelerate adoption and impact
- Linking to other similar efforts beyond Europe & exploring potential for cross-sector collaboration

Community

- INESC TEC (RTO)
- Politecnico di Milano (University)
- Fraunhofer IEE (RTO)
- IRT SystemX (RTO)
- University of Amsterdam (University)
- RTE (TSO)
- TenneT (TSO)
- enliteAI (SME)

Code quality

- All code on Github: https://github.com/AI4REALNET
- Documentation is being improved
- Code is being tested in the AI4REALNET project &integration of the different components is planned for April 2026 (VM at RTE)

Releases

- The components have been developed and tested in the project
- New releases are planned for
  - March 2026
  - September 2026
  - March 2027
- The partners have an interest in keeping the effort alive and expanding it, and potentially exploring it as a development and testing stack for human-centric AI assistants
- Collaboration with a testing and experimentation facility (AI-EFFECT) and possibility of additional EU-funding

AI4REALNET

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