Artelys | OPTIMIZATION SOLUTIONS

ÉCOLE POLYTECHNIQUE STEEM GRADUATE DEGREE

E4C INTERDISCIPLINARY CENTER

Coriolis Seminars for the Environment

Développement Durable à l'X

Trusted-AI tools to support operators in the Energy Transition

Coriolis Seminar, Ecole Polytechnique

2026-01-29

www.artelys.com

Presentation Outline

1. Arteys in a nutshell
2. AI and quantitative techniques for the Energy Transition
3. A walk-through of quantitative techniques at work
4. Next avenues: Foundation models?
5. Q&A

Artelys in a nutshell

Artelys

Artelys is an independent company, founded in 2000, specializing in **decision support**, **modelling** and **optimisation**.

Artelys is headquartered in **Paris**, with local offices in Nantes and Lyon, as well as in **Montreal**, Brussels, Madrid and Milan.

2000
CREATION
Arnaud Renaud

15% per year sustained
GROWTH, 40+ countries,
400+ clients

150+
INTERNATIONAL EXPERTS
Engineers, PhDs

30% to 35% of
activities dedicated to
R&D

SERVICES & CONSULTING

Optimisation,
Data Science
and business expertise

SOFTWARE DEVELOPMENT

Tailored softwares,
Off-the-shelf software suites,
Numerical solvers

STUDIES

Analysis and planning for an efficient energy transition

Our Expertise

Artelys delivers **decision-support solutions**, powered by **quantitative techniques**, with a strong focus on the **energy sector**

Optimisation

- Linear & nonlinear programming
- Mixed integer programming
- Numerical solvers development

Data science & AI

- Descriptive analysis, segmentation
- Visualization & dashboards
- Learning & prediction
- NLP

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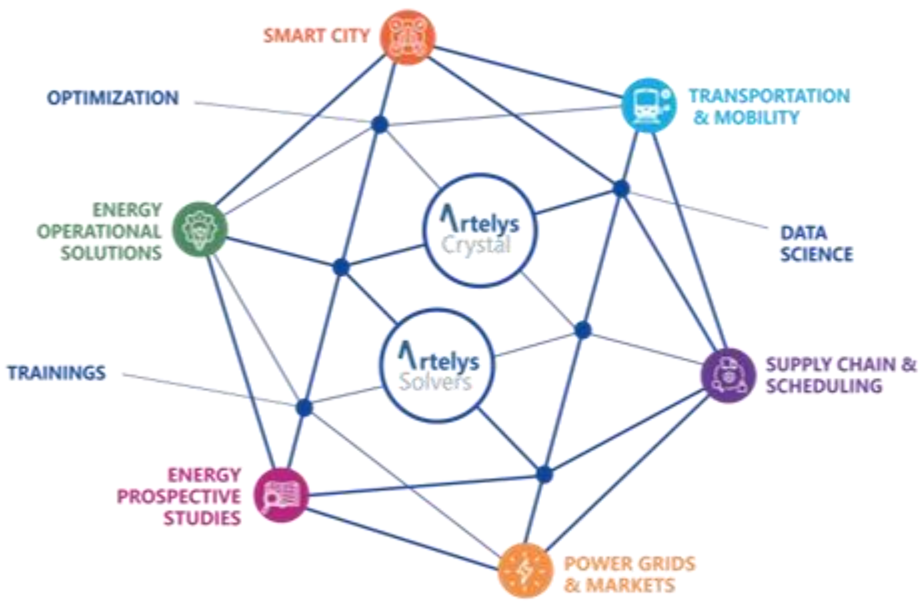


Operational solutions

- Load-flow calculations for TSOs
- Market clearing algorithms
- Assets management optimisers
- Bidding algorithms

Energy prospective

- Energy systems fundamental-based modelling
- Energy transition scenarios
- Cost-benefit analyses
- Consulting & market studies

Recent clients in the energy sector

Public sector / NGOs

- European Commission
- Banque Mondiale
- C40 Cities
- economie – SPF Economie, P.M.E., Classes moyennes et Energie
- Commission de Régulation de l'Énergie
- ADEME – Agence de la Transition Écologique
- Bureau fédéral du Plan – Analyses et prévisions économiques
- AFD – Agence Française de Développement
- giz – Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
- Ressources naturelles Canada / Natural Resources Canada – Canada
- European Climate Foundation
- Agora Energiewende
- atee – Association Technique Énergie Environnement
- Schweizerische Eidgenossenschaft / Confédération suisse / Confederazione Svizzera / Confederaziun svizra – Office fédéral de l'énergie OFEN
- UFE – Union Française de l'Électricité

Infrastructure operators

- Rte – Réseau de transport d'électricité
- GrDF – Gaz Réseau Distribution France
- Statnett
- Enedis – L'électricité en réseau
- elering
- elia
- GreenAlp – Partageons l'énergie
- entsoe
- entsog
- GASGRID
- coreso
- AST
- TSCNET Services
- Svenska Kraftnät
- TenneT
- énergir
- Energinet
- groupe e
- Litgrid

Utilities

- TotalEnergies
- Brookfield Renewable Energy Partners
- EDF
- ENGIE
- Hydro Québec
- CIE

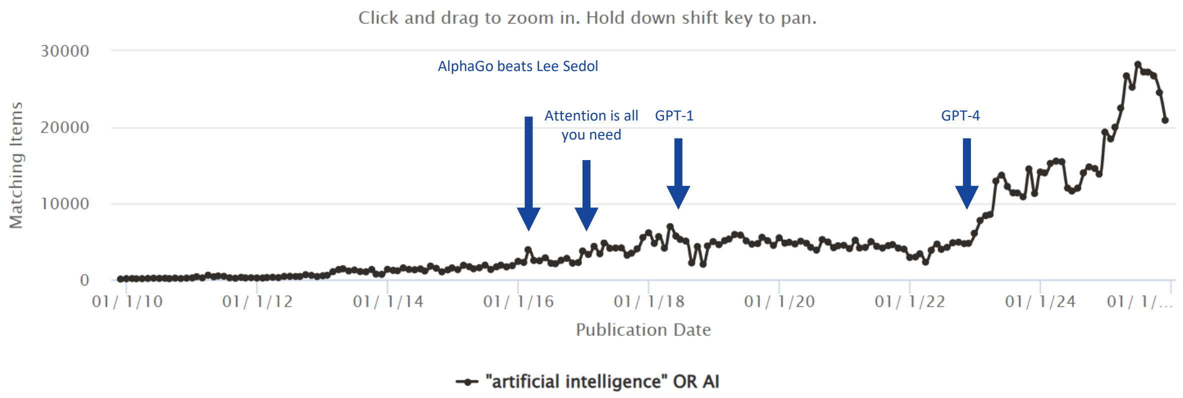
Markets

- EPEX SPOT – European Power Exchange
- eex

~~AI~~ Quantitative techniques for the Energy Transition

Artificial Intelligence: what are we talking about?

A media perspective : Monthly news items featuring « AI » or « Artificial Intelligence » in the main US papers



Source: https://www.mediacloud.org/

From an Energy professional perspective: this AI is not enough -> Quantitative techniques - Applied Mathematics techniques relevant for decision support

Machine Learning, Data Science? **Yes!**

AI as defined above? **Of course!**

Operation research and numerical optimisation? **As well!**

Good old statistics? **Absolutely!**

And all the computer science knowledge to develop tools leveraging those techniques

Quantitative techniques to meet the challenges of energy transition

1 Energy transition plans imply deploying a very large amount of renewable energy:

- U.S. interconnection queue, composed of generation projects waiting for approval to connect, has risen to 1350 GW in 2022 (source).
- Germany plans to install 55 GW of renewable before 2030 (source).

2 But the power grids are already heavily congested:

- U.S. Customers are spending more than USD 6 billion per year on grid congestion charges (source).
- German customers have spent EUR 4,25 billion in 2022 (source).

3 And expanding the grid is a slow process

On average, 10 years to build a new line vs 5 years for grid connection (source).

Quantitative techniques support decision making from planning to operational horizons

HOW? Let's look at some examples

- Mathematical modelling, numerical optimisation and High Performance Computing for Cost Benefit Analysis of interconnexion projects
- Reinforcement Learning for congestion management
- Power systems simulation modules for European Coordination

A walk-through of quantitative techniques at work

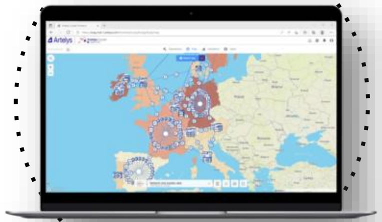
Artelys Crystal Super Grid for CBAs

Artelys Crystal Super Grid (ACSG) is a web-based solution dedicated to the **modelling and optimisation** of **multi-energy systems**, modelling a various range of assets from generation to consumption, through transmission and storage.

The modelling is based on a **bottom-up representation.** It is dedicated to model **multi-energy interconnected systems**

The application handles various **time resolutions** as well as different **geographical** scales

The model optimizes the **generation dispatch** by minimizing the system's costs.



The application incorporates a **high-performance computation service**, combined with an **extensive library** of pre-configured KPIs

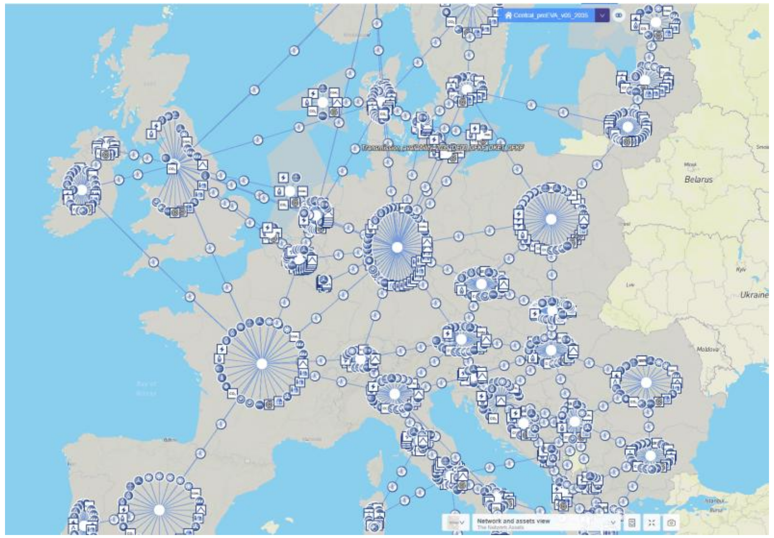
The application can also handle **capacity expansion** as well as capacity expansion planning over successive periods.

The application enables to carry out **numerous sensitivity analysis** by defining a set of variations and launch simulations in parallel with **state-of – the-art optimisation techniques**.

Artelys Crystal Super Grid for CBAs

Ingredients

- A Set of scenarios for the evolution of
- An European system considered at an hourly resolution
- Over few time horizons (e.g. 2030-35-40)
- And a few climatic years
- + An interconnexion project



Associated quantitative techniques and key figures

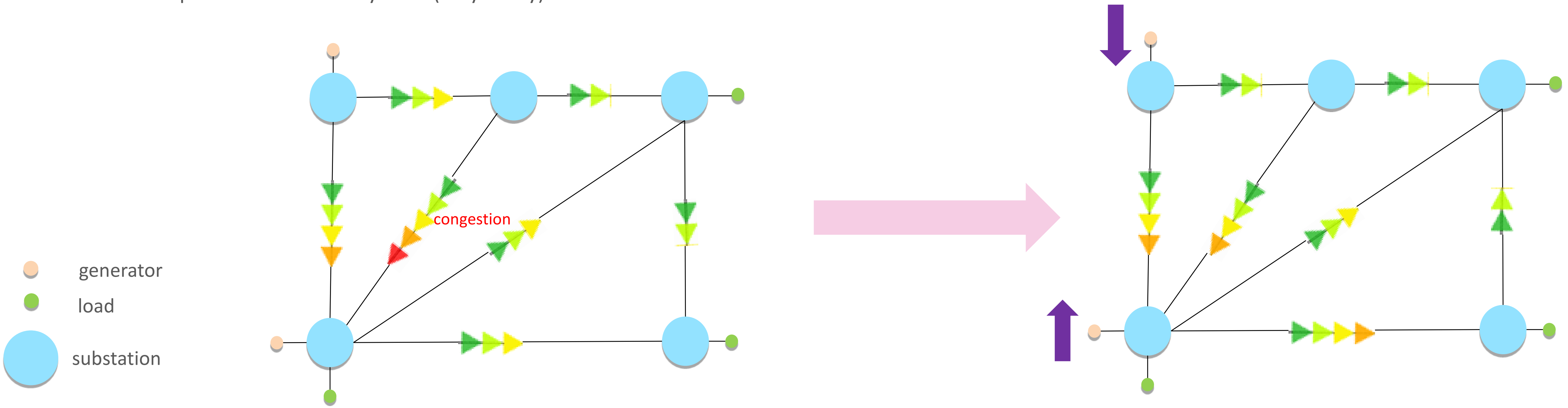
- Assets models (a few **hundreds** assets)
- Probabilistic modelling of outages
- N hourly economic dispatches of a year
    - N = #scenarios x #time horizons x #climatic years x #outage draws
    - N = a few **thousands**
- 1 economic dispatch = A linear program with **millions** of variables and constraints
- **Dozens** of indicators computed over the optimisation results
- Deployement at scale of parallelized computations over HPC ressources
- A few hours of computation on a massive OVH « bare metal » pod
    - **192** cores and **3Tb** of RAM

Reinforcement Learning for congestion management

Question: What are flexibilities?

- When it comes to congestion management, flexibilities are a tool to
  - Anticipate (preventive actions) congestions from a forecasted state of the grid
  - Resolve (curative actions) congestions when they happen

- How ?
  - Redispatch has been vastly used (very costly)



Reinforcement Learning for congestion management

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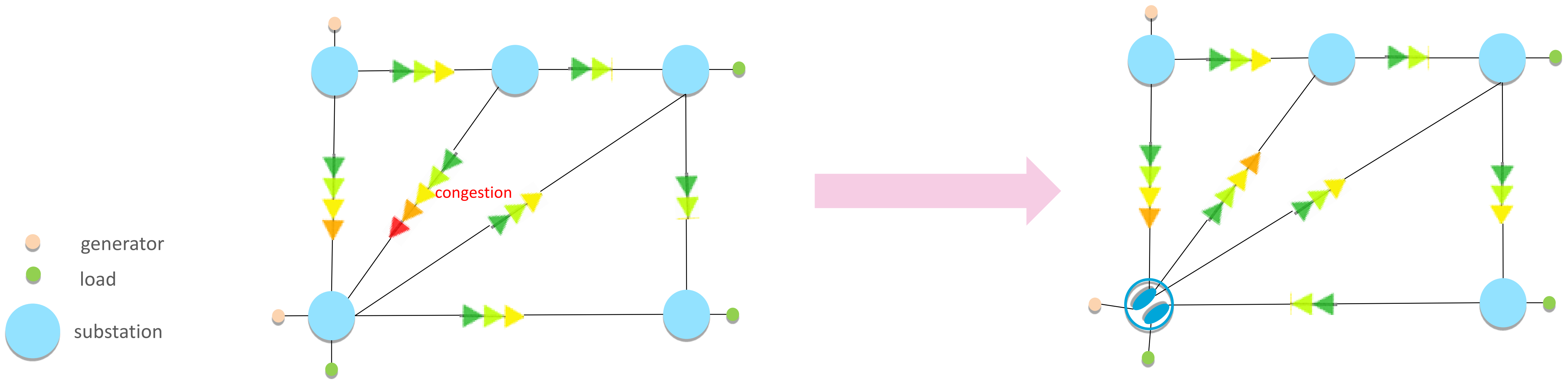
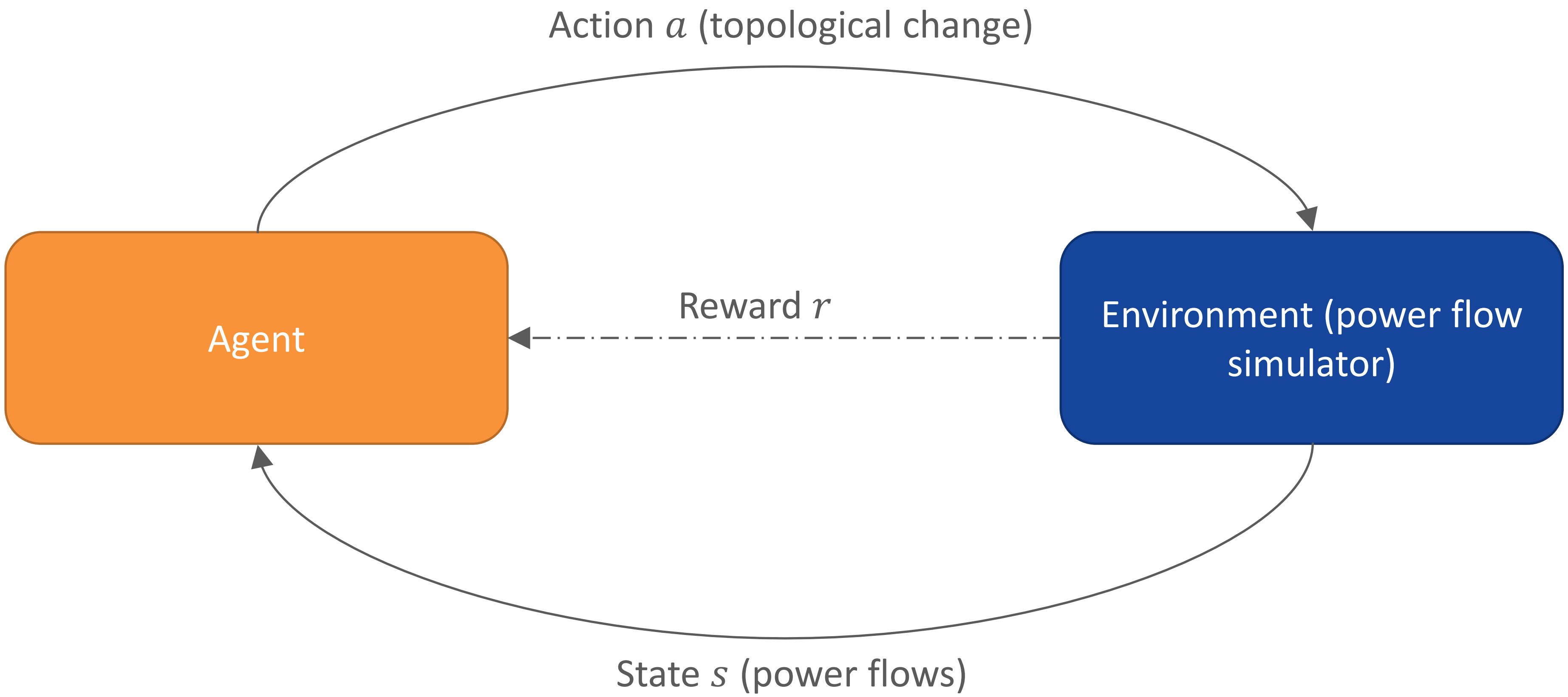
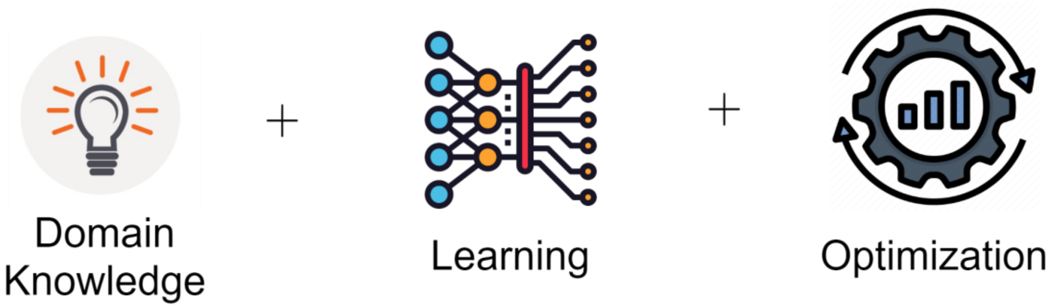
- How ?
  - **There is another way, and it's cheap -> topological actions (challenge: number of possible actions becomes extremely large)**

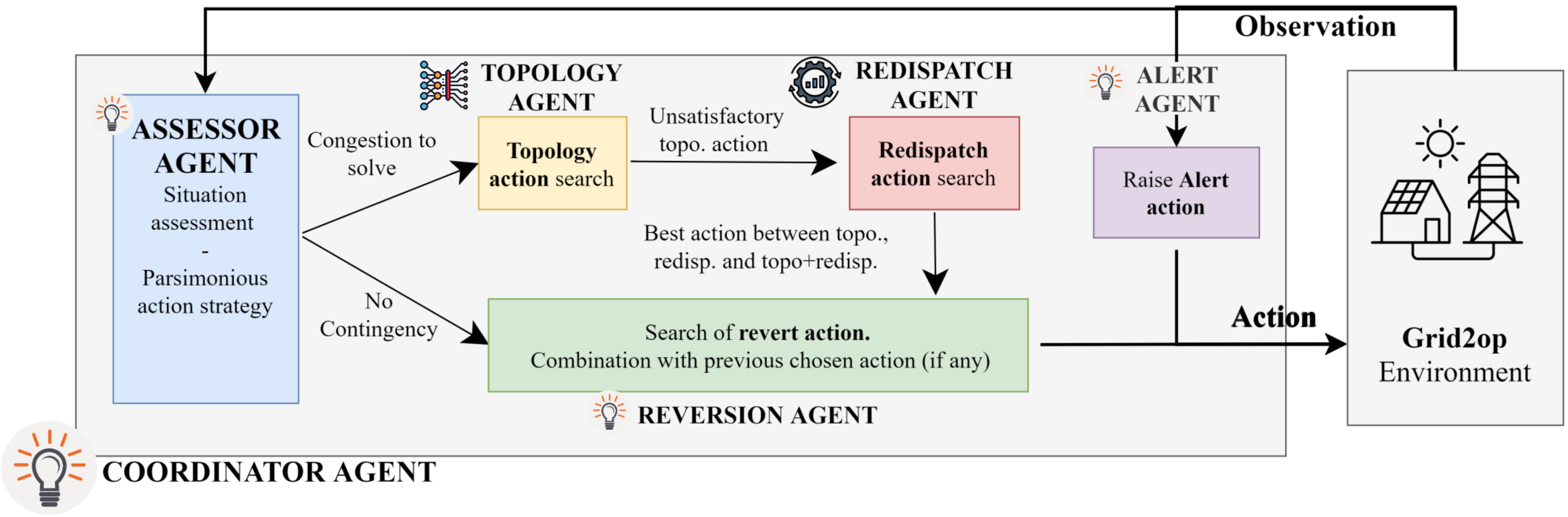


A word about Reinforcement Learning

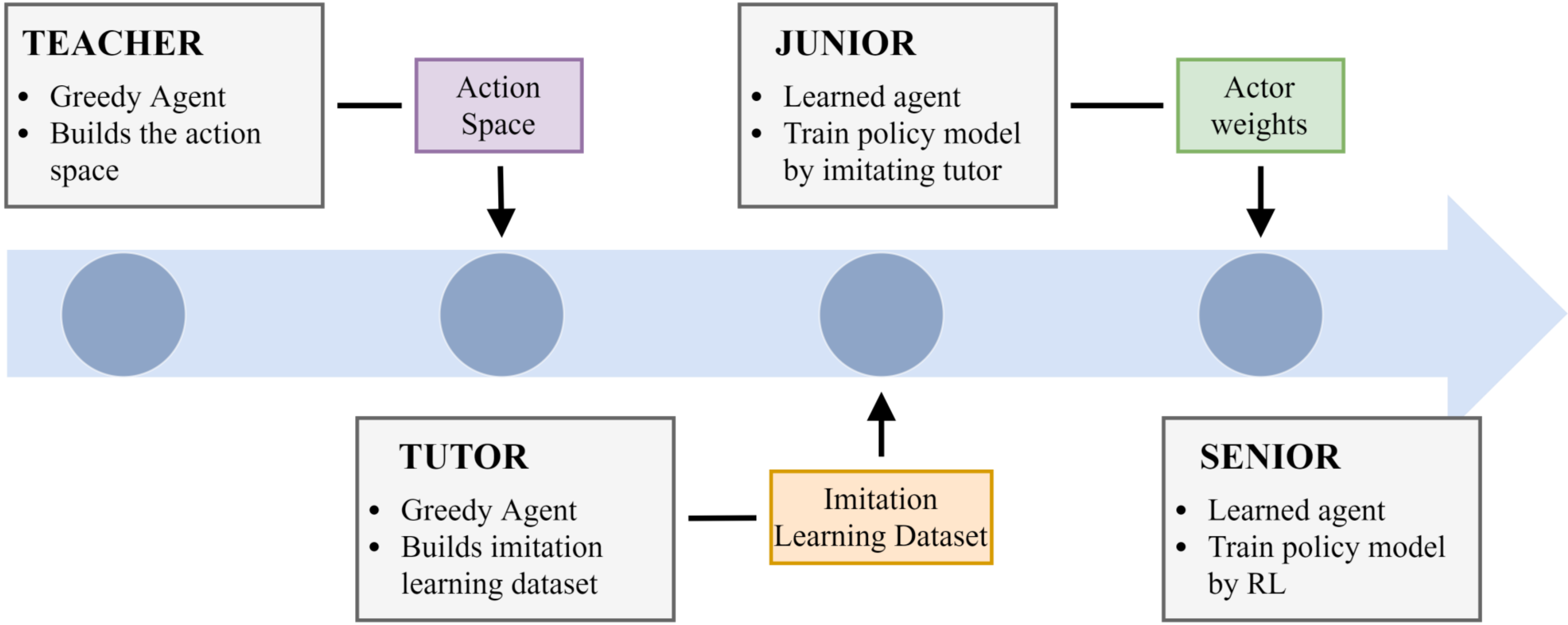


A coordinated Multi-Agents framework





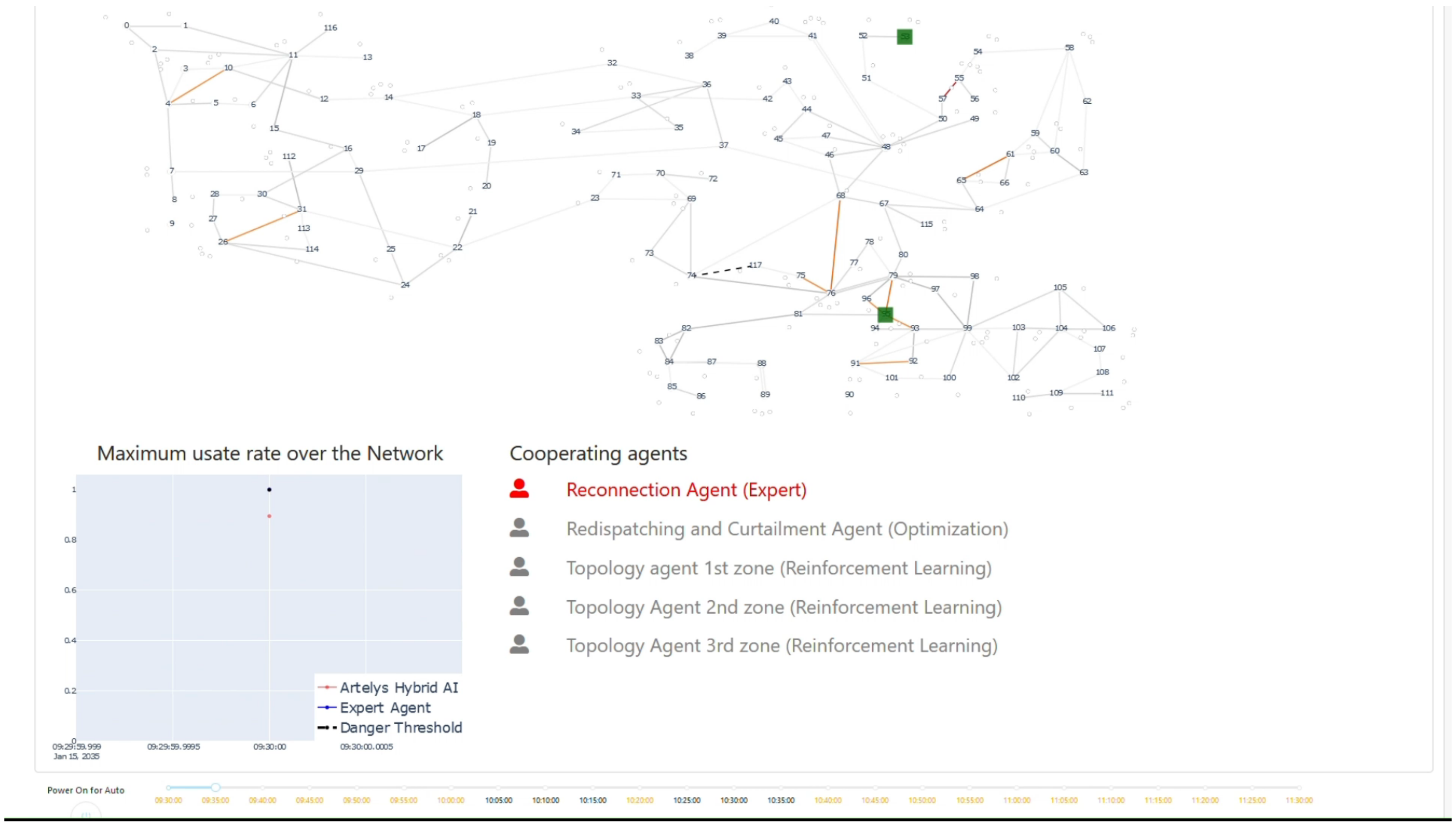
Topology agent – Learning by curriculum



- Learning by curriculum [1] adapted from Lehna et al [2] and previous works on L2RPN

[1] Curriculum learning, Y. Bengio, J. Louradour, R. Collobert, J. Weston, 2009
[2] Managing power grids through topology actions: A comparative study between advanced rule-based and reinforcement learning agents. M. Lehna, J. Viebahn, C. Scholz, A. Marot, et S. Tomforde, 2023

Results of the 2023 L2RPN competition



Example of our agent dealing with a contingency in the 2023 L2RPN competition

Question

- What do you think are the main challenges to go from there to the TSO Operation Room?

Among all your correct answers : Building datasets to train and validate the models & providing the data to the model in operation

PowSyBl: grid modelling and computation framework

- **PowSyBl** is an open-source framework ("Power System Blocks") dedicated to electrical grid modelling and simulation.
  - **LFE governance**
    - Technical steering committee: RTE, Artelys and AIA
  - **Commercial friendly license**
    - Weakly contaminating MPL v2
  - **Large community**
    - 200+ users. Used in daily operations by European Transmission System Operators (TSOs)
  - **Transparency**

LF ENERGY POWSYBL

OpenSSF BEST PRACTICES

Grid computations	Power Flow, OPFs, security analysis, dynamic simulation
Grid formats	CIM, CIM-CGMES, UCTE, Matpower, PSS/E…
User-Friendly	Python interface Network and substation visualization libraries
Grid modelling	Format extensions, Grid Extractions, Merging…
Entreprise grade	Java (numerical C libraries) OpenSSF silver badge Data format version management CI/CD with high standard (code coverage…)

Focus on Open Load Flow

Planning

Operation

Metrix

Grid reinforcement studies

Calculation of grid reinforcement benefits
- With an optimized **economic redispatching** simulator

High performance
- **100 times faster** power flow calculation than standard DC load flow
- Tuned integrated open-source ILP solver

Flexible computation
- **3 calculation modes:** LF, non costly actions, full redispatching.

Open Load Flow

Security analysis, Sensitivity factors

AC and DC Load Flow
- Grid Merging
- Advanced grid modeling (remote control…)

Security Analysis
- N-k contingency analysis
- Pre- and Post-contingency actions
- HPC distribution

Sensitivity Analysis
- PTDF, PSDF on a list of network elements, tuned for OPF

Open RAO

Remedial actions optimization

Large selection of Remedial Actions
- Topological actions, PST and HVDC setpoints, redispatching
- Pre-and post-contingency

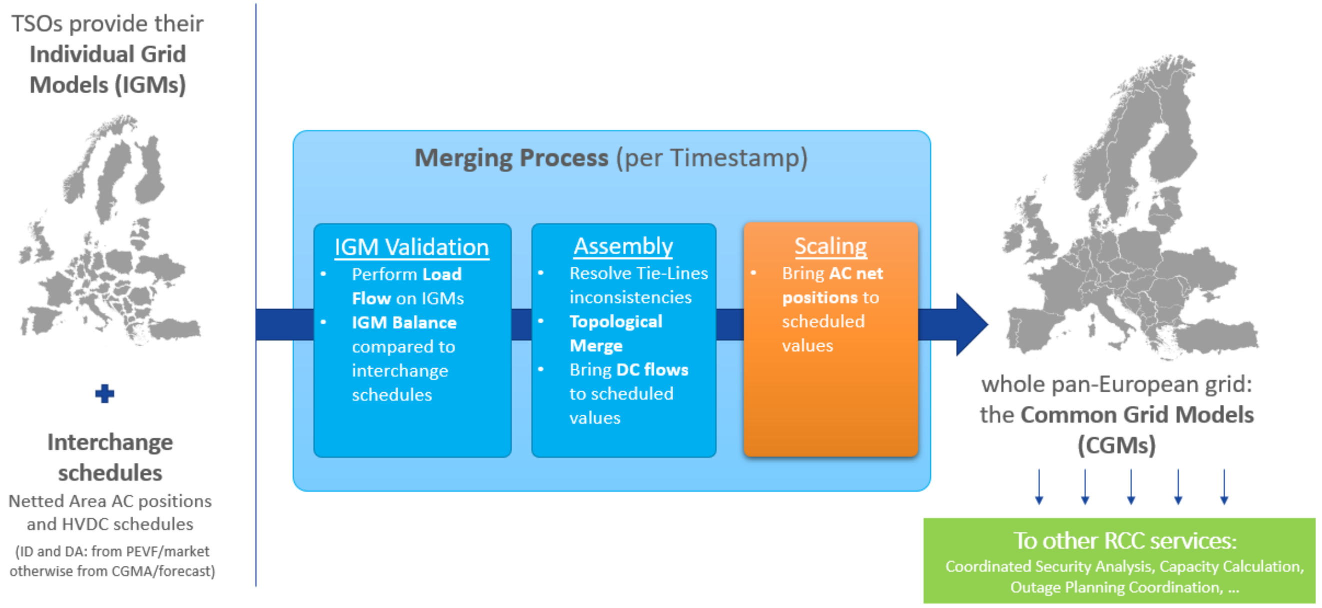
Capacity calculation
- Optimal action selection to **maximize power flows** between two bidding zones.

Redispatching & countertrading
- Minimize congestion management costs

PowSyBl-Open Load Flow – CorNet and European Merging Function

Context

CorNet program: 30+ Transmission System Operators (TSOs) covering 5 regions and 2 Regional Coordination Centers (RCCs) have decided to build a **common IT platform** to perform the coordination tasks from day-ahead to real-time.



Challenge

A **single pan-European grid model** encompassing all participants is necessary to obtain a holistic view of the systems, validate load flow computations and coordinate cross border energy exchanges.

Methodology

Using **Open-Load Flow**, the approach consists in developing a process that validates then merges TSOs' Individual Grid Models into a Common Grid Model, namely the **European Merging Function**.

Live at CorNet since December 2024.

Open Load Flow – European Merging Function - going further

The EMF serves as the **backbone for a series of processes under implementation**, to boost the efficiency and the security of the European power systems.

Merging & Load flow Analysis

Assess the loading conditions of power grid elements:

- Validation of models from **+30 TSOs**
- Core region merged network of **120.000 nodes**
- AC/DC LF aligned with **ENTSO-E requirements**
- **High performance** requirements

Cost sharing

Assess the costs for countries to deploy corrective measures

- Application of a **central optimizer** (RAO)
- Transition from "Requester Pays" to "Polluter Pays" principle
- **Sophisticated calculation** chain for Cost sharing key determination

IT Systems for RCCs

coreso TSCNET Services

Security Analysis

Assess the system response to contingencies:

- 24 Timestamps to process on merged network
- **10.000 contingencies**, 6.000 monitored elements
- **High performance** requirements (total time: 5 mins).
- **Parallelized** processes.

Capacity Calculation

Assess the max transfer capacities at borders to ensure secure power trading between countries

- **Different time horizons** to be considered (Intra-Day, Day-Ahead, Monthly, Annual,…)
- **From monthly to annual** capacity calculations for **SWE region**
- **High performance** requirements

LF ENERGY POWSYBL

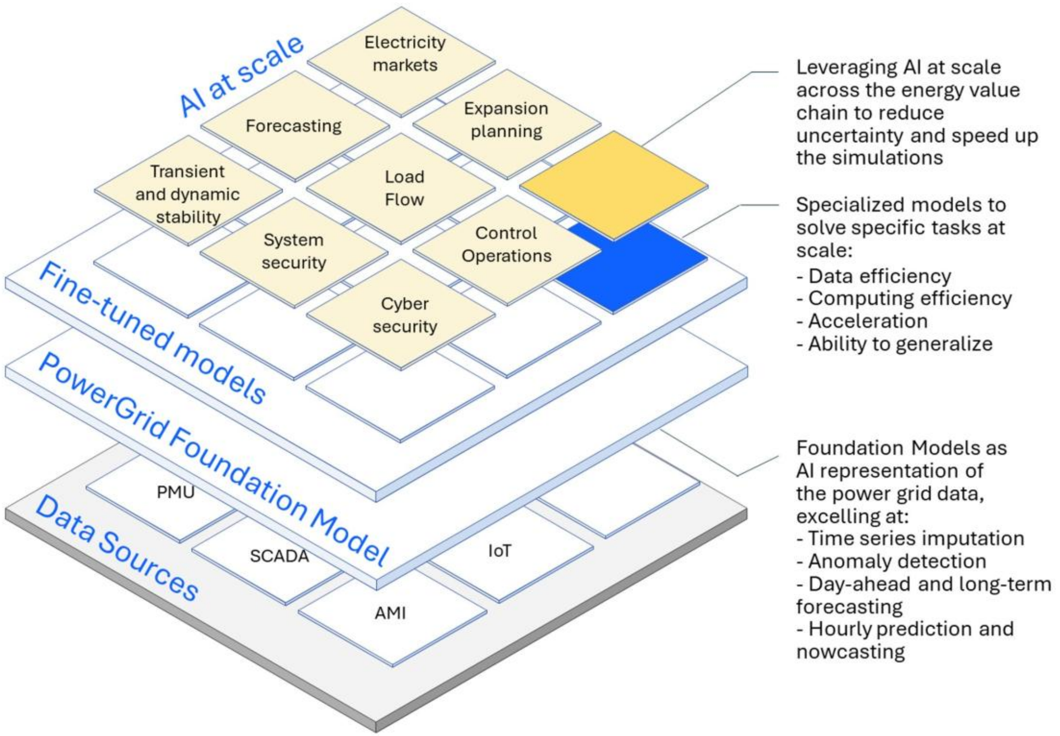
Foundation models

Foundation models: what's to come next?

- The EU organised the first workshop on **European AI Foundation Models for the Energy Grids** on December 8th 2025

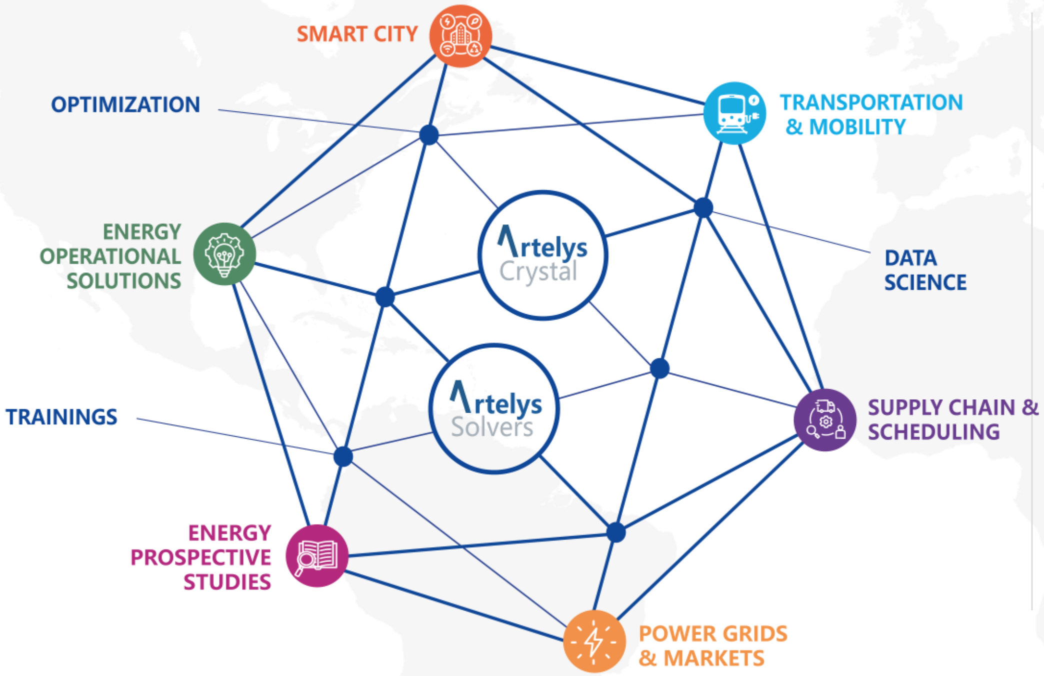
- Working Groups are bringing togheter TSOs, DSOs, AI developers, technology providers, Testing and Experimentation Facilities (TEFs), research partners and EU institutions to **define common priorities**

- **3 Working Groups**
  - Strategic use cases, benchmarking & validation strategy
  - Data, governance & interoperability
  - Model Development, Training Pipeline & MLOps Framework



https://lfenergy.org/projects/gridfm/

Thank You!



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