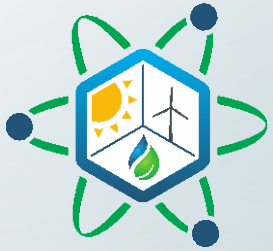

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Real-Time Optimization with ORCA

April 6, 2023

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Idaho National Laboratory

ORCA

- Optimization of Real-Time Capacity Allocation
  - Objective: at every time horizon, maximizing revenue in anticipation of system dynamics.
  - Inputs: real-time measurements, market locational marginal prices.
  - Outputs: optimal energy allocations.
  - Modeling: linear optimization with reduced-order models.
- What does it help solve?
  - Problem of optimal energy dispatch in integrated energy system.
  - Problem of information exchanges between physical and virtual assets.
  - Problem of data management, storage, and visualizations for complex systems with custom ontology

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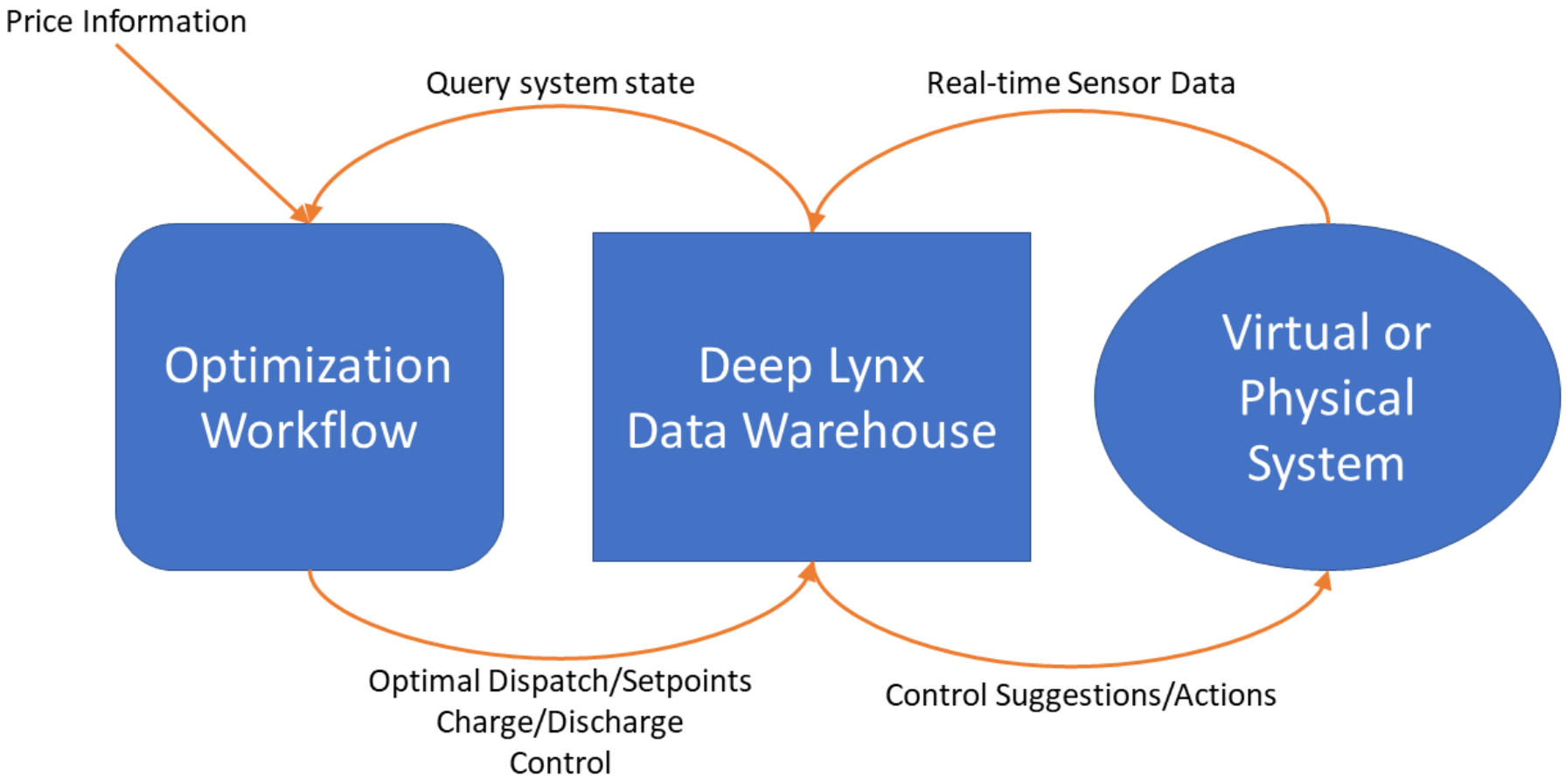
RTO Components



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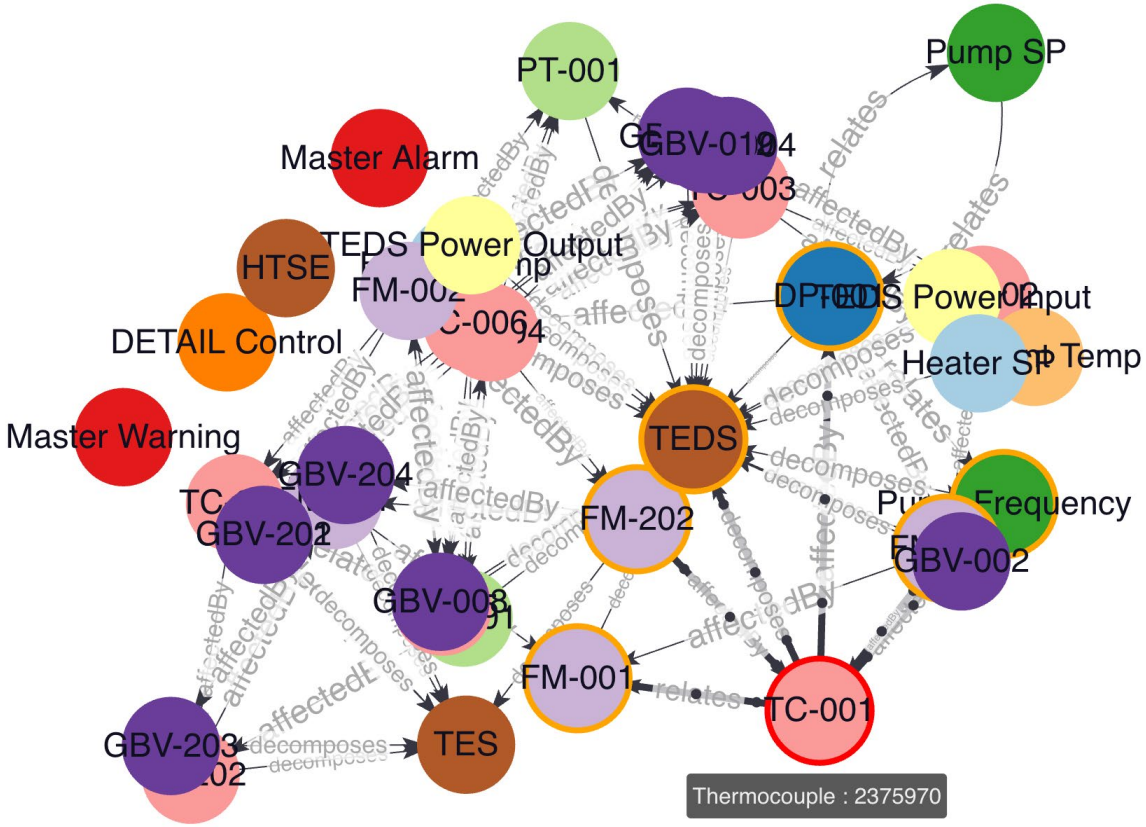
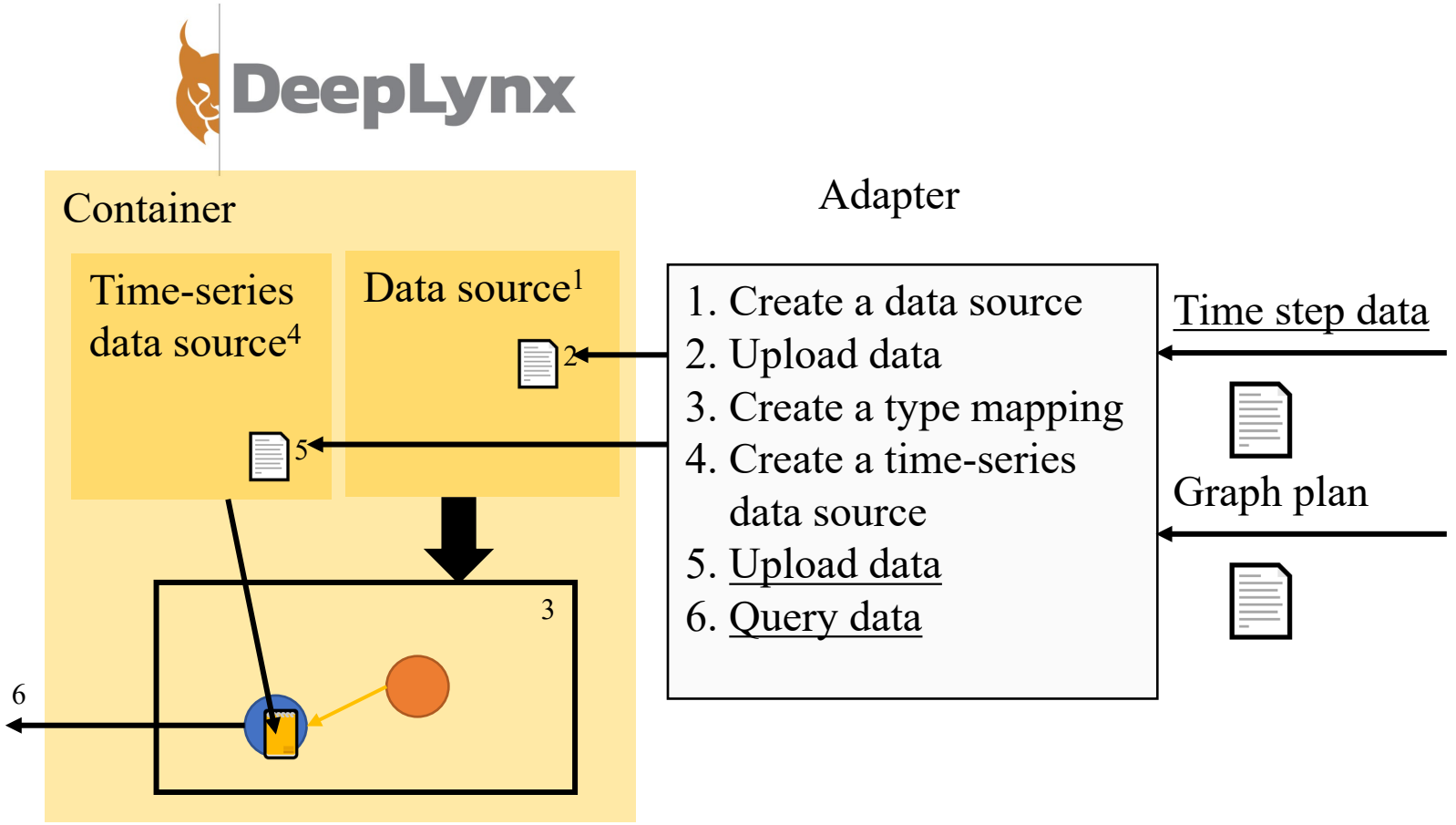
Deep Lynx Data Warehouse

- Open-source data warehouse software developed at INL
- Graph database governed by custom ontology
  - Data Integration Aggregated Model and Ontology (DIAMOND)
  - Data stored as nodes in the graph
  - Defined relationships represent how each node is associated with other nodes
  - Also allows for storing data as time-series tables, connected to nodes



Deep Lynx Adapter



IES Real-Time Economic Optimization

- IES optimization occurs at multiple time scales
  - “Real-Time” = days, hours, minutes, etc.
- Operation optimization of IES
  - Integration of IES with digital twin
    - RTO sits between M&S and operations
  - How do we operate optimally?
    - Maximize profits
    - Production scheduling
    - Arbitrage
- Why RTO?
  - $$$

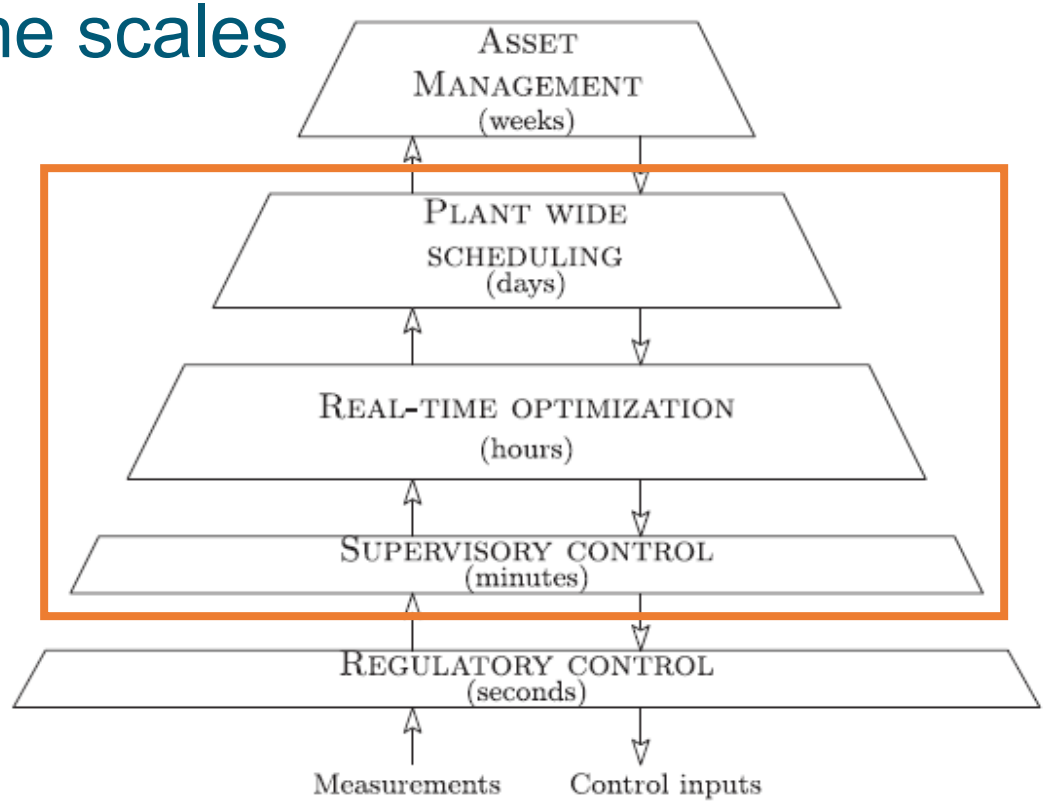


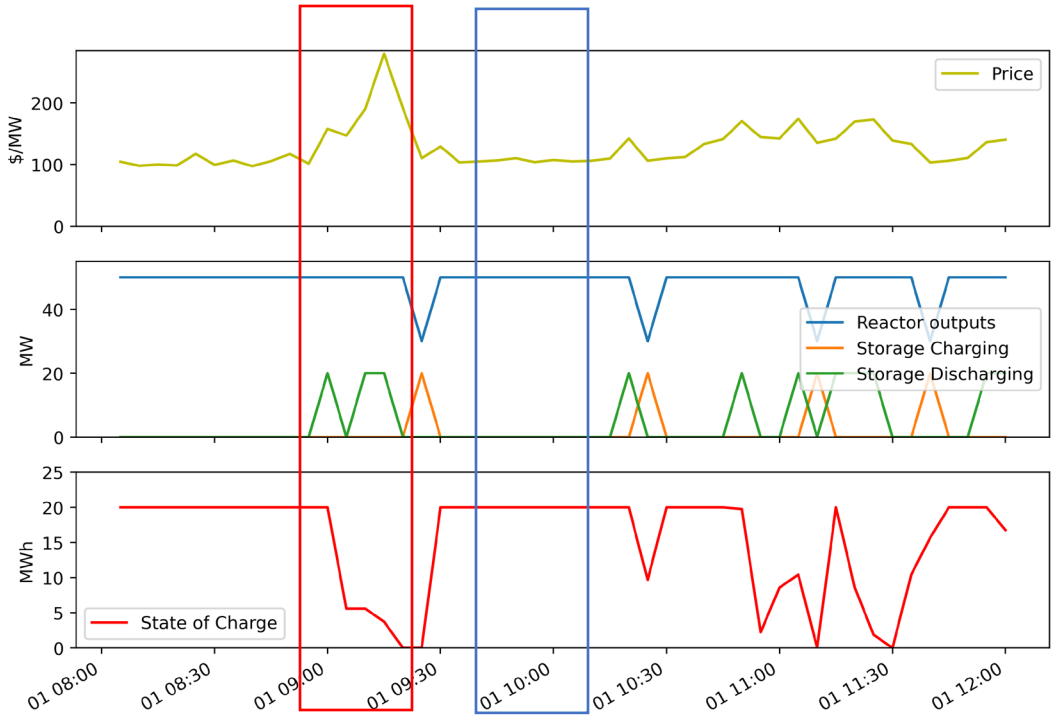
Fig. 1. Typical control hierarchy in process control.

Krishnamoorthy et al. 2018

Optimization Workflow

- Economic Model Predictive Control/Receding Horizon Optimization
  - Forecast LMP forward in time based on history.
  - Use reduced-order model to predict IES system dynamics (power plants + energy storage) and revenues.
  - Optimize dispatch for maximum revenue
  - Use dispatch for next time step only
  - $t = t + 1$, repeat
- Pyomo – Python based open-source optimization modeling language
  - Reduced-order model calibrated by RAVEN
  - Linear optimization based on open-source solver glpk

When prices are high, predicting IES system dynamics and discharging energy storages for maximum revenue.



Charging energy storages when prices are low

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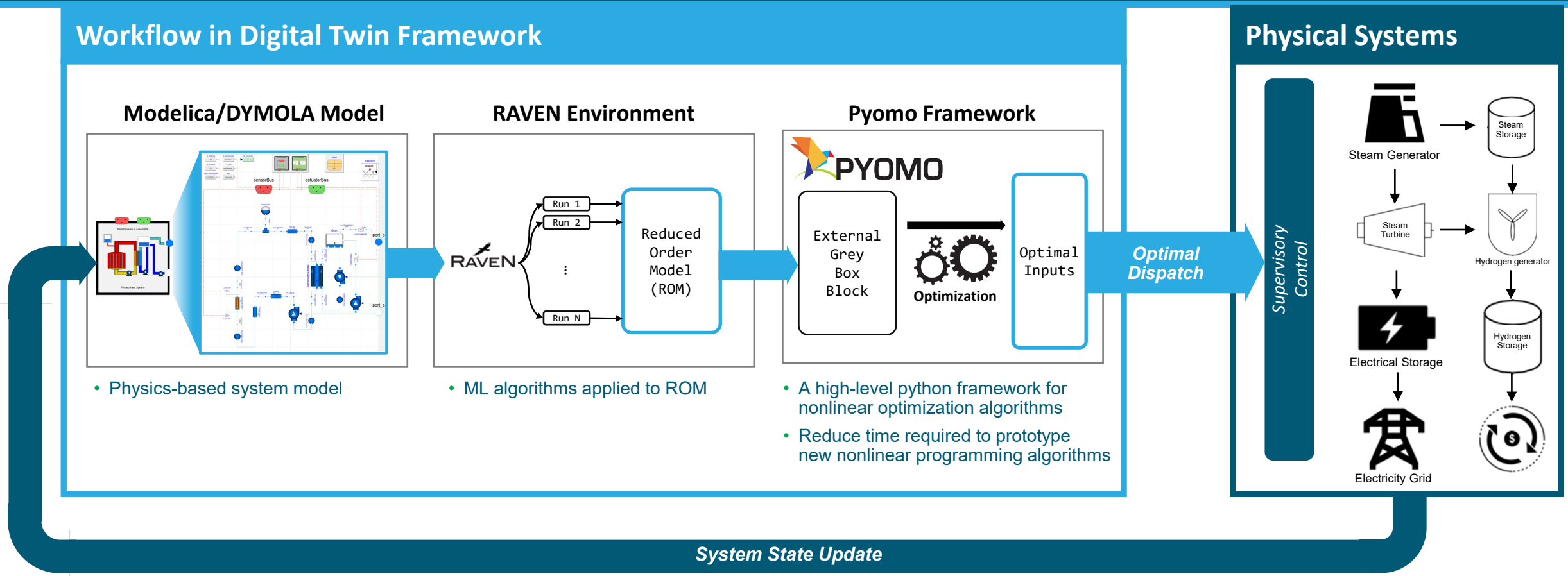
Optimization Initial Approach: Grey Box Model



- Physics-based system model
- ML algorithms applied to ROM
- A high-level python framework for nonlinear optimization algorithms
- Reduce time required to prototype new nonlinear programming algorithms

- Many types of models:
  - Black box – no information: only inputs → outputs
  - Grey box – some information: inputs → outputs, derivatives (Jacobians, Hessians, etc.)
  - White box – all information: inputs → outputs, functional form, derivatives

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Optimization Current Approach: State Space

- Current approach
  - State space ROM:
    - $x_k = Ax_{k-1} + Bu_k$
    - $y_k = Cx_k$

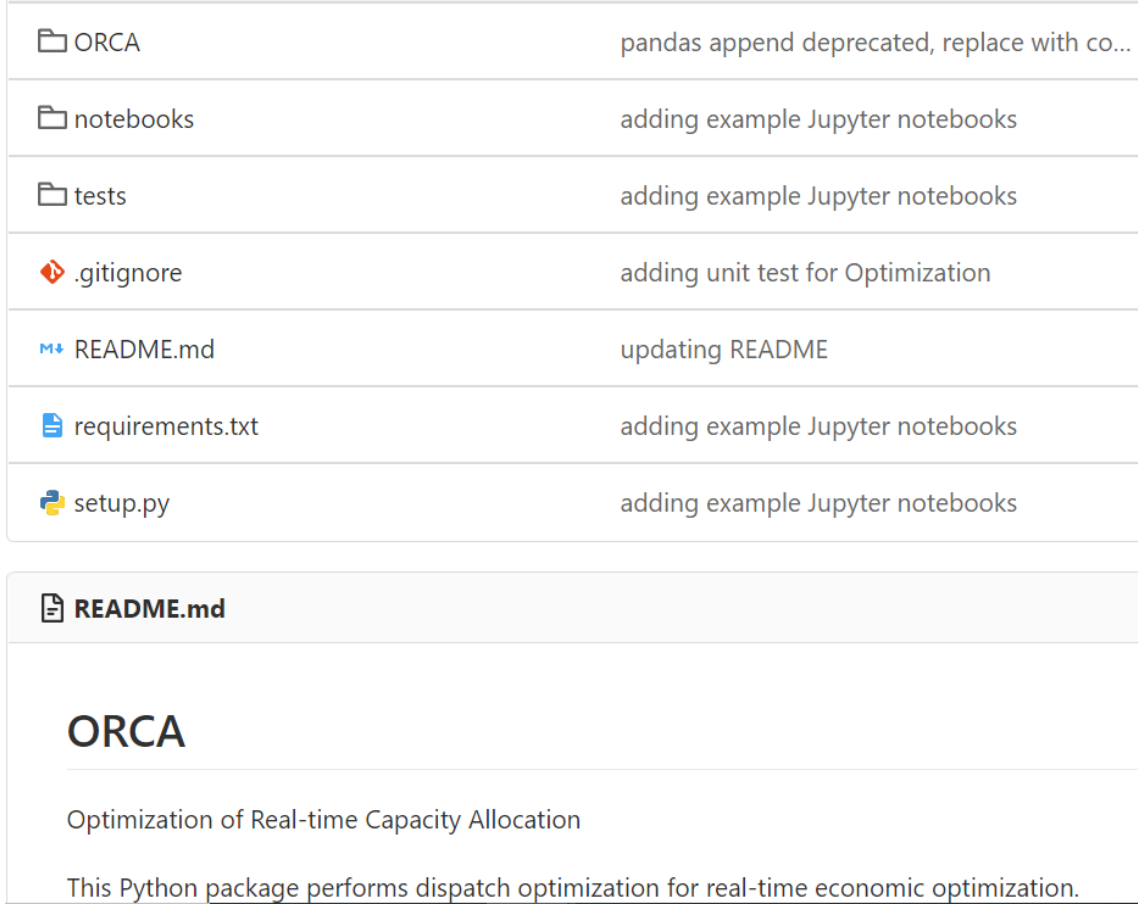
- x: states – state of charge, etc. may not be directly measurable
- u: control – things that can be manipulated/changed
- y: measurements – directly measured, may be function of states (correlation to charge, different in physical system)

  - Advantages:
    - Use matrices to build algebraic expressions in Pyomo
    - Very fast solution times

  - Disadvantages:
    - Applicable to specific applications
    - Limited by training data and ROM creation process

Current Work

- Deep Lynx
  - Utility development for ORCA
- ORCA development
  - Non-linear programming
  - Automate construction workflow
  - Externalize HERON dispatch optimization tools
- Virtual/Physical Demonstration
  - Leverage model development from other work packages



ORCA	pandas append deprecated, replace with co...
notebooks	adding example Jupyter notebooks
tests	adding example Jupyter notebooks
.gitignore	adding unit test for Optimization
README.md	updating README
requirements.txt	adding example Jupyter notebooks
setup.py	adding example Jupyter notebooks

README.md

ORCA

Optimization of Real-time Capacity Allocation

This Python package performs dispatch optimization for real-time economic optimization.

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Beyond FY23

- Include additional considerations in optimization
  - Safety, reliability, FARM, operational constraints
- Expand ORCA
  - Expand with more optimization options
  - Integrate with other FORCE tools
- Demonstrations on other DETAIL or physical systems
  - HTSE
  - NRIC
  - SPHERE
  - Site Hydrogen facility
  - Other

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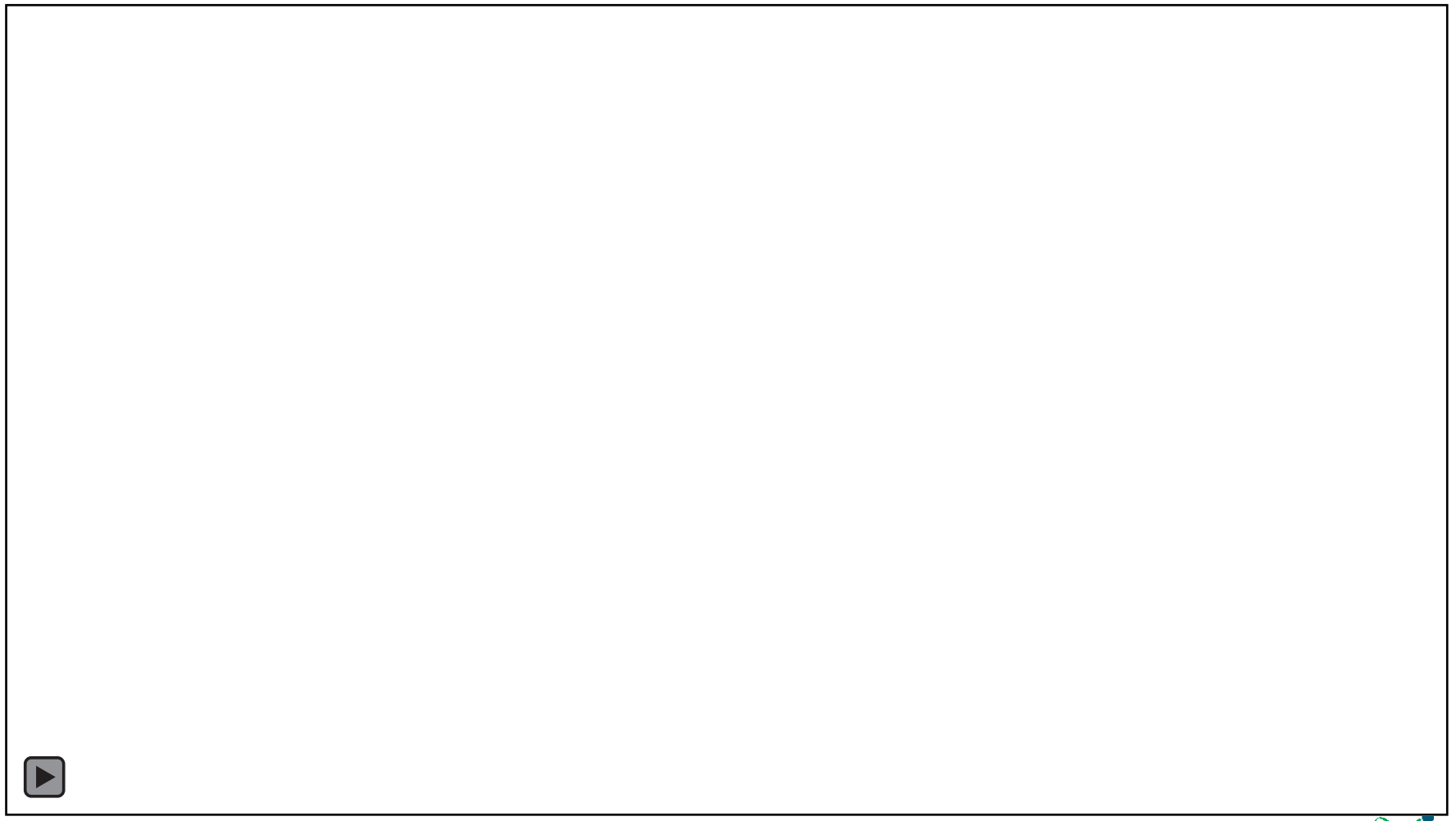
Demo



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Timeseries Data Demo

Questions

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