Gurobi in Energy and Power

Resilience, Optimization, Agility

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GUROBI OPTIMIZATION

Agenda

Optimization In Power and Energy

Challenges & Gurobi Role

- Complexity
- Real-time Optimization
- Uncertainty
- Multi-Objectives

Our Partners, Customers and Consulting

- Worldwide
- Japan

Q&A

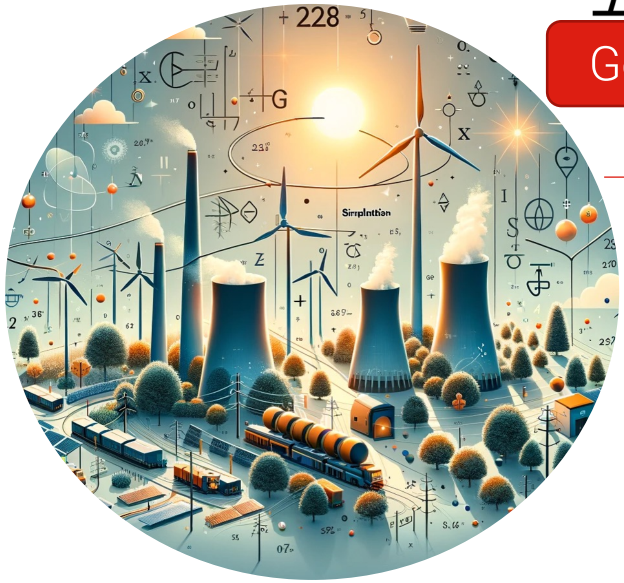
Optimization In Power and Energy

"How do our customers in energy sectors use Gurobi?"

Optimization of Power Systems

From Plant to Plug

Generation → Transmission → Distribution → Trading



AI Generated Image

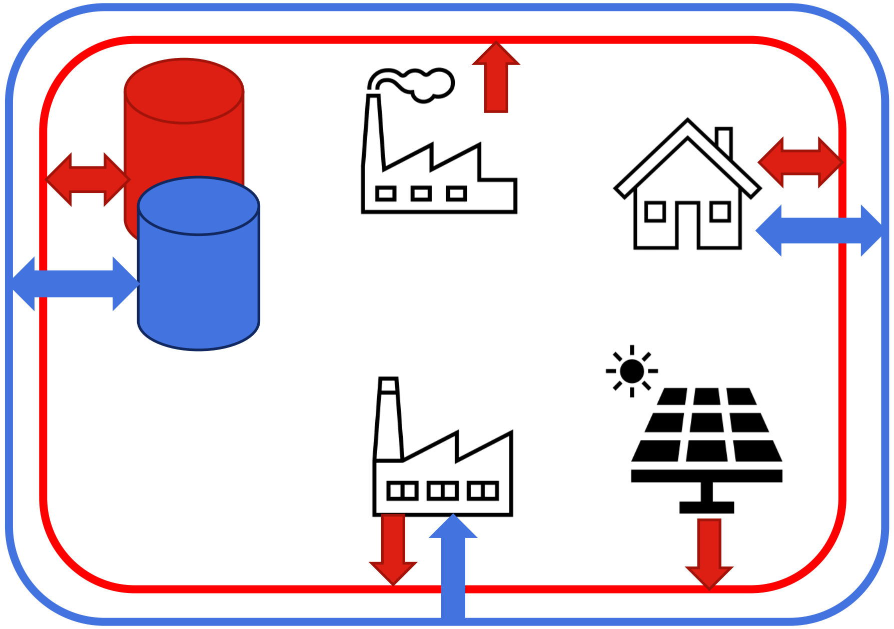
Operational Planning

Operational Design

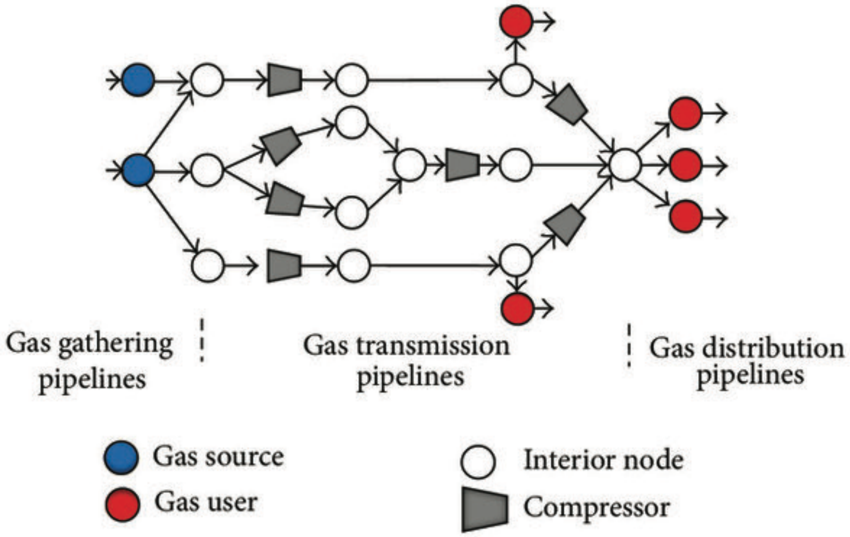
AI Generated Image

Optimization of Energy Systems

Save the Valuable Resources



Heating/Cooling network



Natural Gas Transmission

Industries Transformed by Optimization

Electrical Power

- Electrical power deregulated in the late 1990s
  - Need to create a market for electricity
- Early solution techniques
  - Heuristics (Lagrangian relaxation)
  - MILP (lots of models; no real usage)
- EPRI report, June 1989:
  - "Mixed-integer programming (MIP) is a powerful modeling tool…. 'They are, however, theoretically complicated and computationally cumbersome'"
  - 7-day unit commitment model could not be solved to optimality
- DIMACS meeting 1999:
  - Bob Bixby demonstrated that MIP had improved to the point where practical power models could be solved
    - 7-day unit commitment model solved to optimality in 22 minutes
- Within a few years, nearly every grid operator in the world was using MIP to solve these models

Photo by Matthew Henry on Unsplash

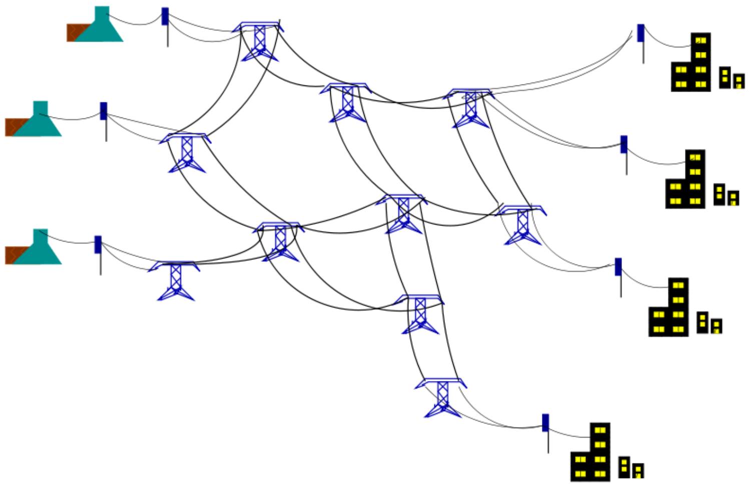
Challenges and Gurobi Role

"Gurobi helps you beating planning challenges"

Challenges and Gurobi Role

Complexity

Alternating Current (AC) Optimal Power Flow (AC-OPF)



We are given a power system, i.e., a network of

- Generators
- Power lines and transformers
- Buses (nodes)
- Each bus has a load, i.e., numerical demand for power generators, lines, transformers, and buses (nodes) with power demands.

Objective: meet demands at minimum cost

Cost: Operating Cost

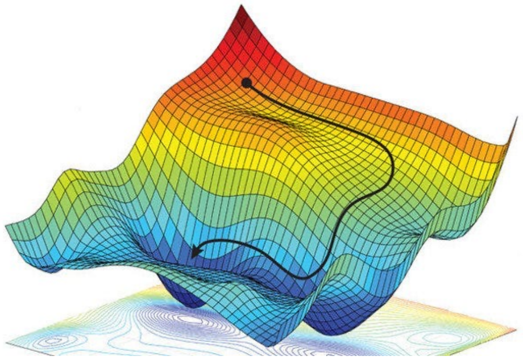
Note: power flows following the **laws of physics**

Challenges and Gurobi Role

Complexity

- Model Size:
  - Large-scale Power System
  - Millions of Variables and Constraints
  - Interdependency among systems

- Power flows following the laws of physics
  - Quadratic
  - Nonlinear
  - Non-Convex



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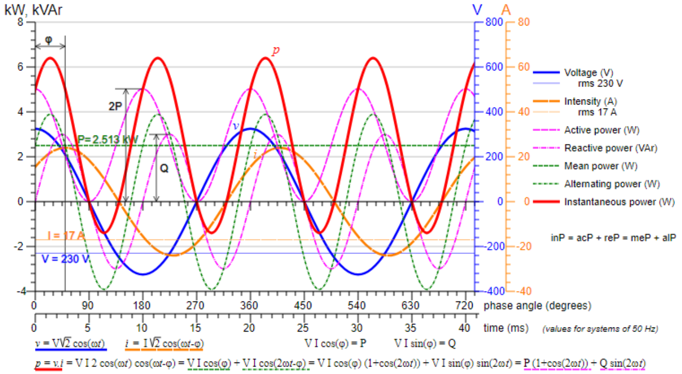

https://en.wikipedia.org/wiki/AC_power

Challenges and Gurobi Role

Beating Complexity

- Model Size:
  - Large-scale Power System
  - Millions of Variables and Constraints
  - Interdependency among systems
- Power flows following the laws of physics
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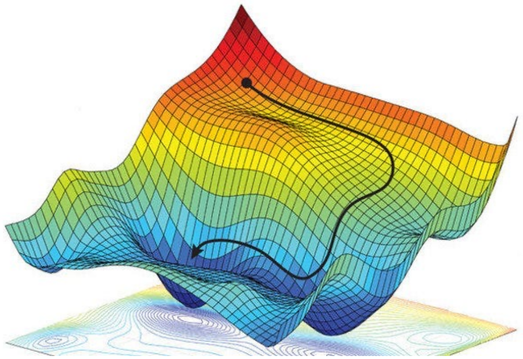
- Automatic reduction for model size: Presolve, …
- Find a feasible solution quickly: Heuristics, …
- Parallel and Sequential Optimization
- and More ….



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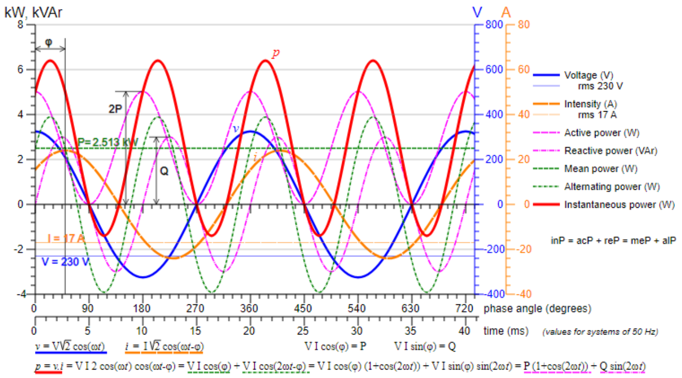

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Challenges and Gurobi Role

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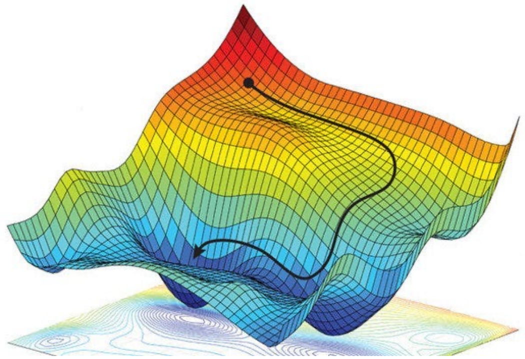

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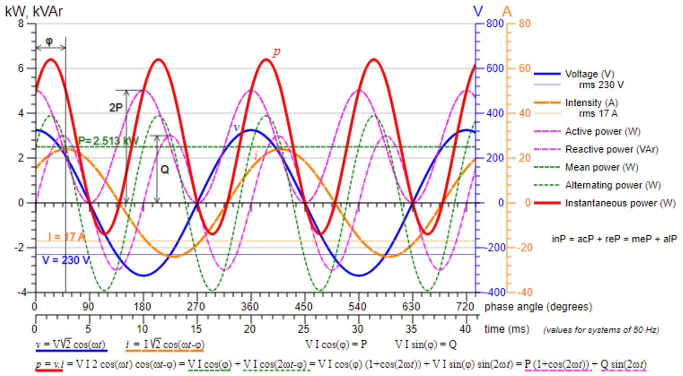

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- Special Functions: Sin() , Cos() , Exp(), …
- Piecewise linear approximation (Ramp constraints: instant power curve)
- NonConvex parameter
- Latest version of nonlinear features
- General Constrains (Max output power..)
- and More ….

Challenges and Gurobi Role

Real-time Optimization

Enhancing Grid Reliability and Resilience with Real-Time Optimization

1. Immediate Response to Unforeseen Events
   - Real-time optimization systems can quickly adapt to sudden changes in electricity demand, ensuring continuous power supply during peak usage times or unexpected demand surges.

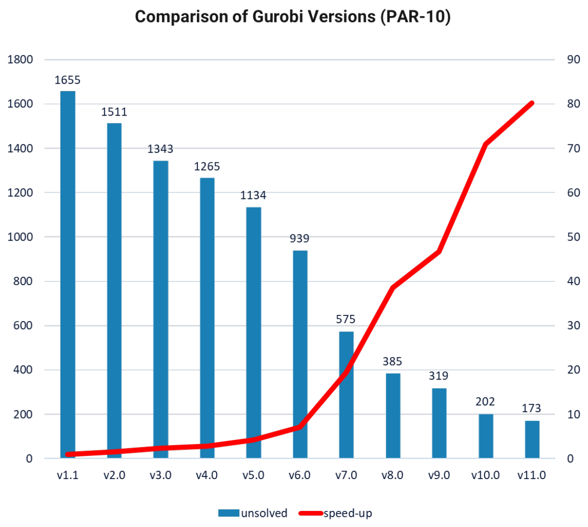
2. Mitigation of Equipment Failure
   - Automated monitoring and real-time optimization enable the early detection of equipment anomalies, allowing for preemptive maintenance or rerouting of power to prevent outages.

3. Adaptation to Extreme Weather Conditions
   - Real-time optimization facilitates dynamic grid management during extreme weather events, minimizing disruptions by adjusting to changes in generation capacity and demand patterns

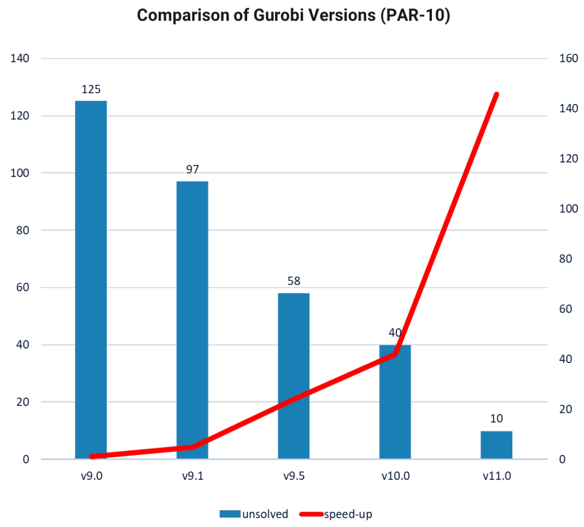
Challenges and Gurobi Role

Real-time Optimization

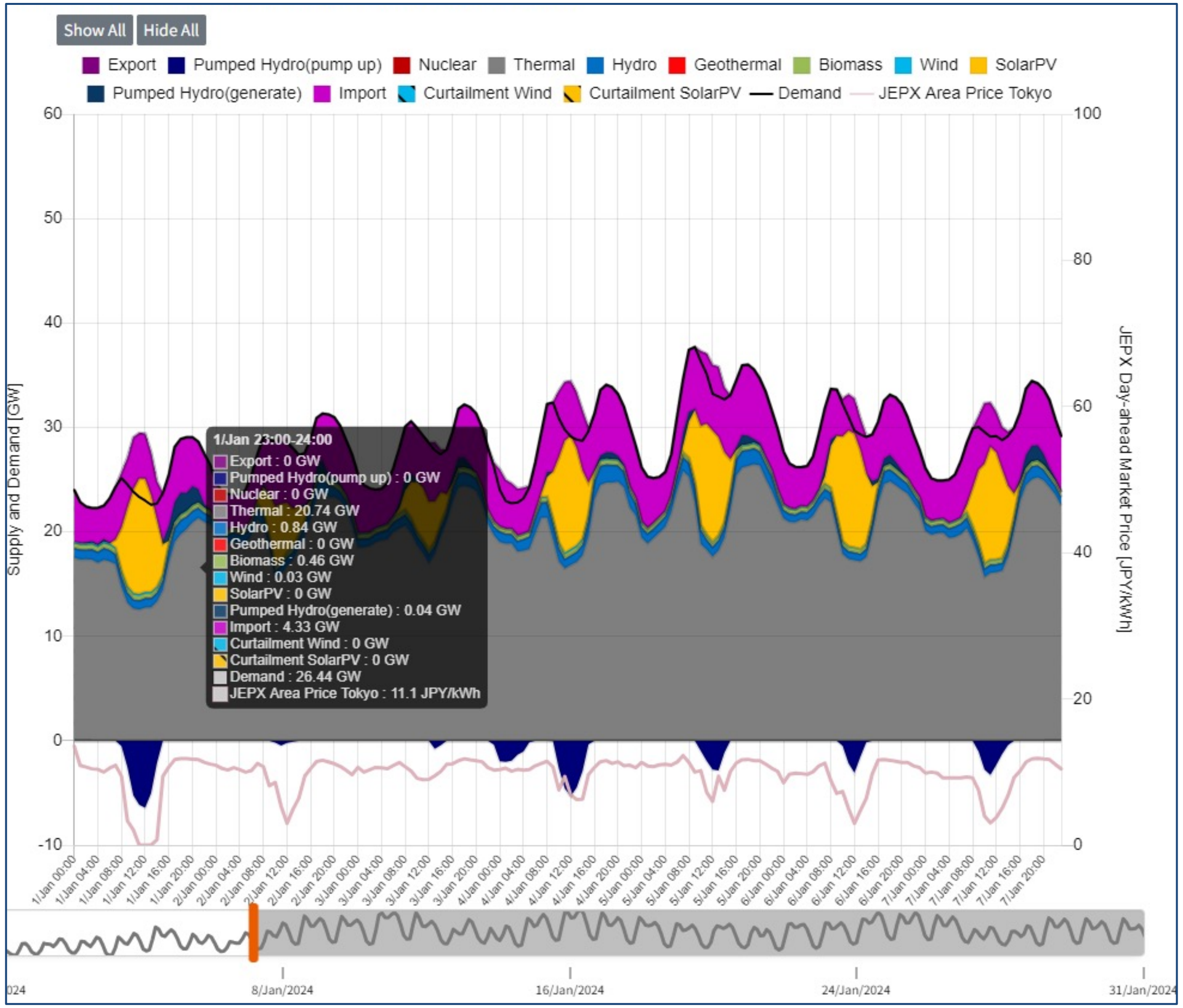
- ➢ Weekly Power Generation Plan.
  - ➢ Daily Power Generation Plan.
    - ➢ Hourly Power Generation Plan.
      - ➢ Real-time responsive Plan.



MILP



Non-convex MIQCP



Energy Planning Challenges

Overcoming Uncertainty

- Uncertainties can significantly impact the reliability, cost, and environmental sustainability of energy systems.
- Avoid uncertainty surprises using Gurobi Multi-Scenario Model

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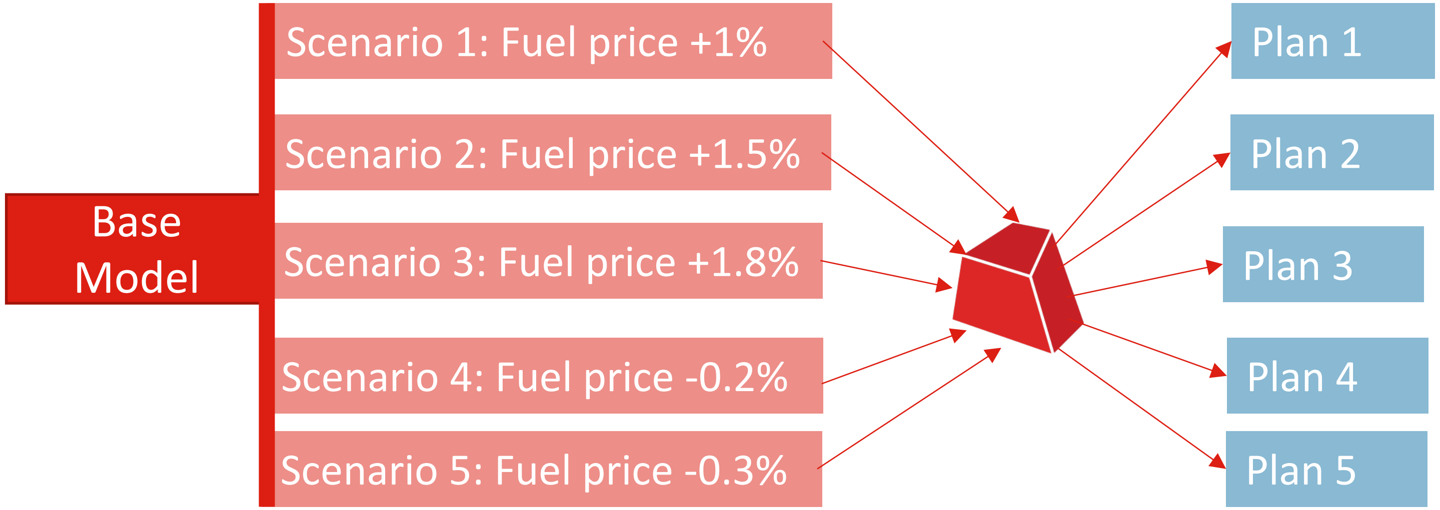

Energy Planning Challenges

Overcoming Uncertainty

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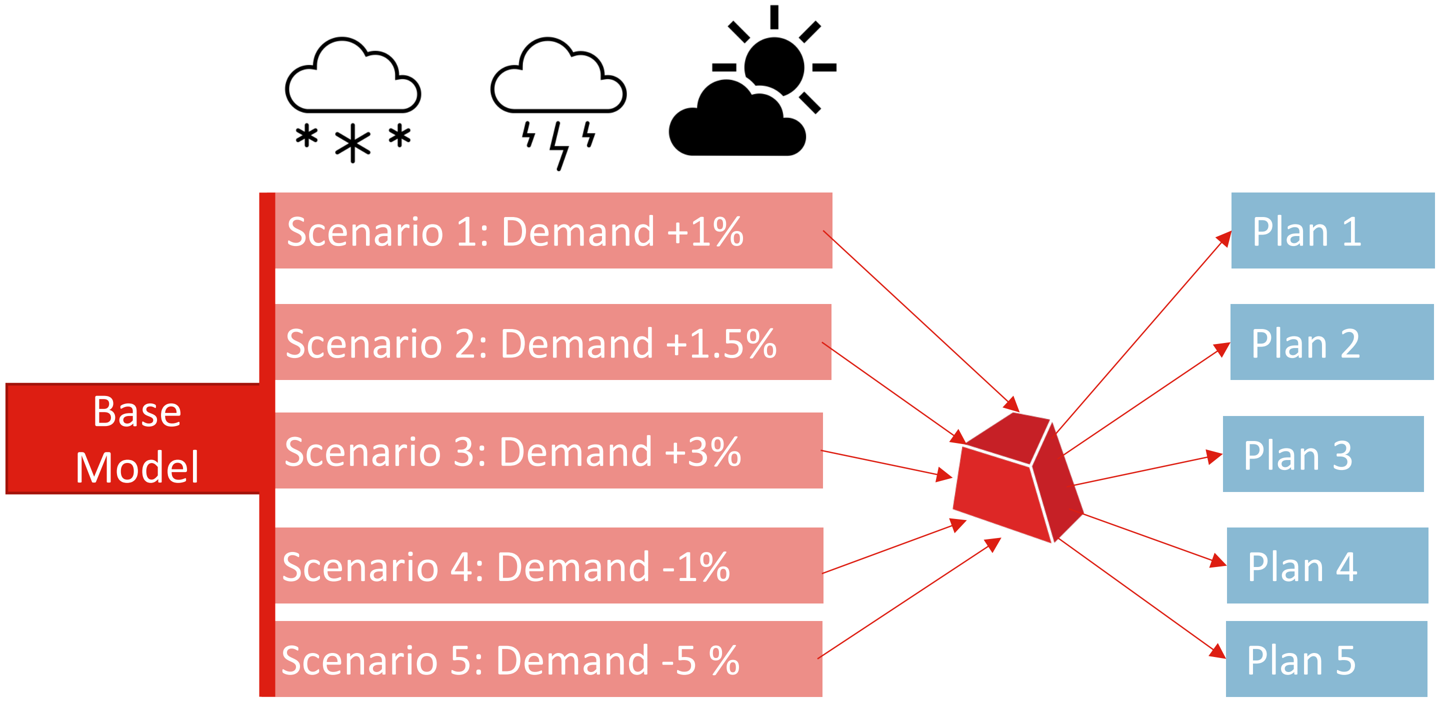


Energy Planning Challenges

Leveraging Multi-Objective Models

General model

Minimize Z
S.T.
$Z = \Sigma \cdots$
…
End.

Multiple objectives

Blended-Objective model

Minimize w1*Z1+w2*Z2
S.T.
$Z1 = \Sigma \cdots$
$Z2 = \Sigma \cdots$
…
End.

※ w1,w2: appropriate constants

Hierarchical-Objective model

Minimize Z1
Minimize Z2
S.T.
$Z1 = \Sigma \cdots$
$Z2 = \Sigma \cdots$
…
End.

Energy Planning Challenges

Leveraging Multi-Objective Models

- Optimize two or more objectives simultaneously (sometimes conflicting)
- Some real-objectives: Unit Commitment problem Objectives

```
model.setObjectiveN(0, GenStartupCost,priority=2)
model.setObjectiveN(1, FuelCost,priority=1)
model.setObjectiveN(2, CO2Emissions,priority=0)
```

Our Partners, Customers and Consulting

The Power of collaboration

European Clients

- 14 Transmission or Electricity System Operators
- 5 large Software vendors in the Eco-System
- 1 regional Security Coordinator
- 2 regulators

References/Logos upon request.

Success Case Studies

Results

- Identify optimal resource scenarios every few minutes
- Reduce customer power bills up to 10%

Optimizing Distributed Energy Assets

With Gurobi, Advanced Microgrid Solutions can identify optimal resource scenarios every few minutes—reducing customer power bills up to 10%.

Advanced Microgrid Solutions

Advanced MicroGrid Solutions (AMS) installs advanced energy storage systems in buildings to lower energy costs for consumers and provide clean, instant load reduction to electric utilities.

Industry: Power and Utilities
Location: Americas
Use Cases: Automation, Cost Reduction, Logistics

Results

- Identify optimal resource scenarios every few minutes
- Reduce customer power bills up to 10%

The San Onofre Nuclear Generating Station, located south of San Clemente, California, just outside of Los Angeles, opened in 1968. Due to its close proximity to several active tectonic faults, it posed a danger to the eight million people living within the 50-mile radius of the plant. This would not be allowed in today's highly regulated environment, but in 1968, the safety regulations that governed the locations of nuclear power plants were scant. In 2009, the plant's reactors received an upgrade designed to last 20 years. However, after the Fukushima disaster in Japan, new regulations ultimately forced the shutdown of the San Onofre site in 2013.

This closure meant that roughly 2,000 MW of power generation capacity was taken offline, creating a 20% power shortage to large portions of Southern California, with no obvious location for a

2012 with a focus on the design and management of energy storage systems at host customer sites. The customer base consists of many large consumers of power, such as manufacturing plants, large office buildings and water/wastewater treatment facilities.

AMS receives revenue through two sources:

- Their share in the savings obtained by the host customer
- Signed contracts with utility companies to provide capacity for the grid

The basic business model for power storage is simply to buy low and sell high. AMS charges batteries by purchasing power from the grid when demand (and price) are low and discharges batteries to feed power to the grid when demand is high.

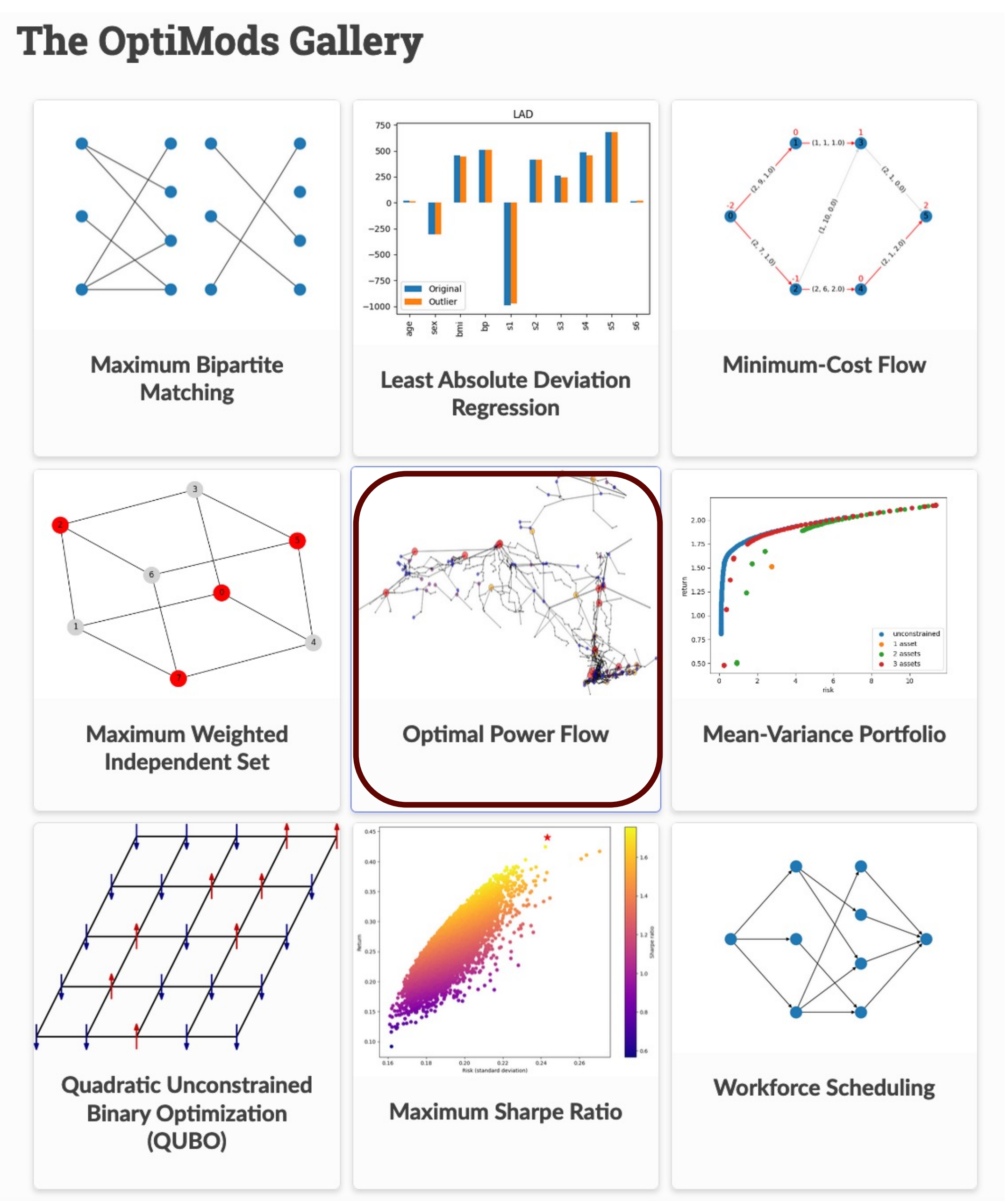
Gurobi Japan Consulting Servies in Energy Sector

Japan: 70% of Japanese Power Generation Companies use Gurobi

- ❑ Hydro-power, Thermal Power, Pumped-Storage, Renewal Power Planet, and integrated Power systems.
- ❑ Short-short term Planning (weekly, Hourly)
- ❑ Long-term Planning (Monthly, Annual)
- ❑ Real-time and disruptive optimization.
- ❑ Gurobi Japan Provides Energy Consulting Services (Modeling, Development, Training).

OptiMods

- Tools to solve specific optimization problems
- Have data-driven APIs and integrate with the greater Python ecosystem
- Take data in “natural form”, return a solution in “natural form”
- Solve mathematical optimization problems using Gurobi’s MIP technology without the need to dive into mathematical modeling



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Performance Tuning

- We need to solve an optimization problem every 5 minutes. What settings should we use to consistently find the best possible solutions in this timeframe?
- Can you help us reduce the time it takes to find high-quality solutions for our model instances?
- We are using a variety of custom parameter settings. Are these settings still beneficial for the latest version of Gurobi?

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April 2024

Thank You

For more information: gurobi.com