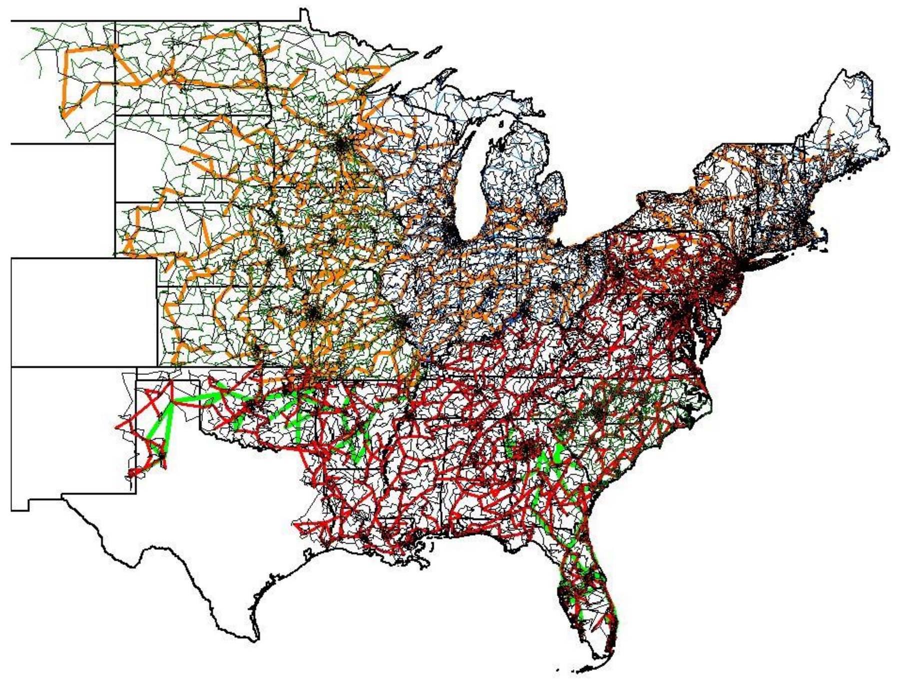
Grid Optimization: AC OPF Software

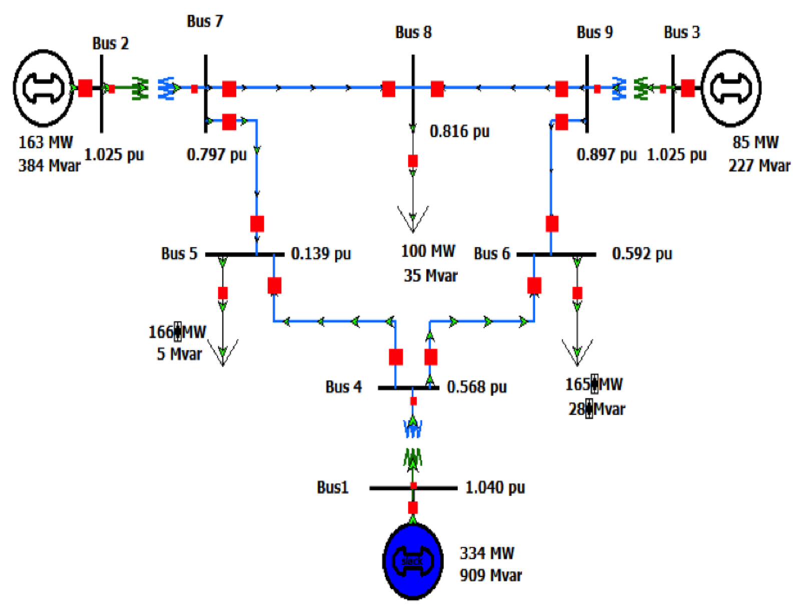
Problem

•AC Optimal Power Flow (AC OPF) helps decide the best way to use power sources, storage, and loads in the grid.
•It's hard to solve because it's large and complex.
•Solving it is important for building a smarter, more efficient, and affordable electric grid.



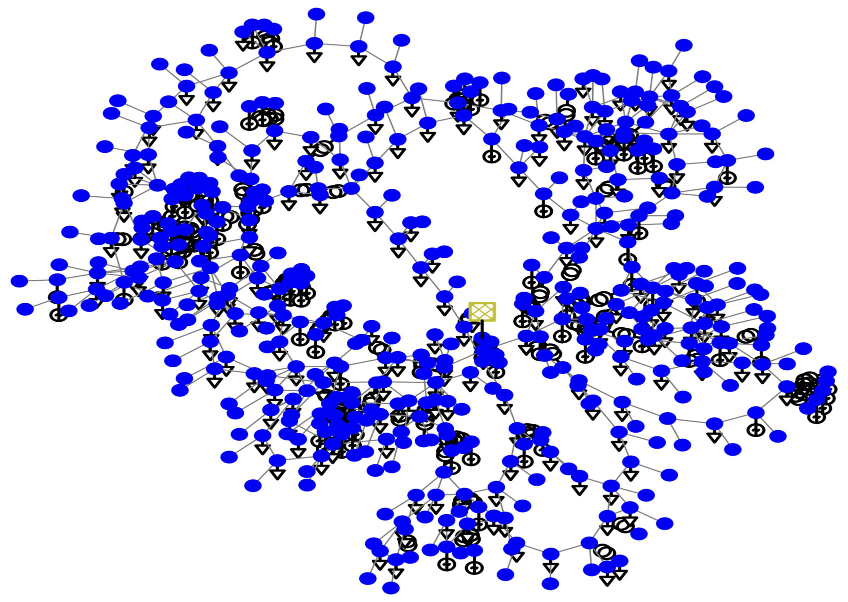
Objective

•Build software to solve the AC OPF problem, a complex, large-scale optimization task for power grids.
•Focus on ARPA-E's GO Competition Challenge #1, with plans to expand to Challenges #2 and #3.



Key Features

- **Multi-Solver Support**
  Integrates IPOPT and Gurobi for optimal performance
- **Large-Scale Capability**
  Handles power grids from 9-bus to 80,000+ bus systems
- **Smart Constraint Management**
  Automatically enforces power balance and safety limits
- **Industry Standard Compliance**
  Compatible with ARPA-E GO Competition formats
- **Intelligent Analysis**
  Generates clear reports with visual optimization results
- **Robust Problem Solving**
  Uses slack variables to ensure stable solutions

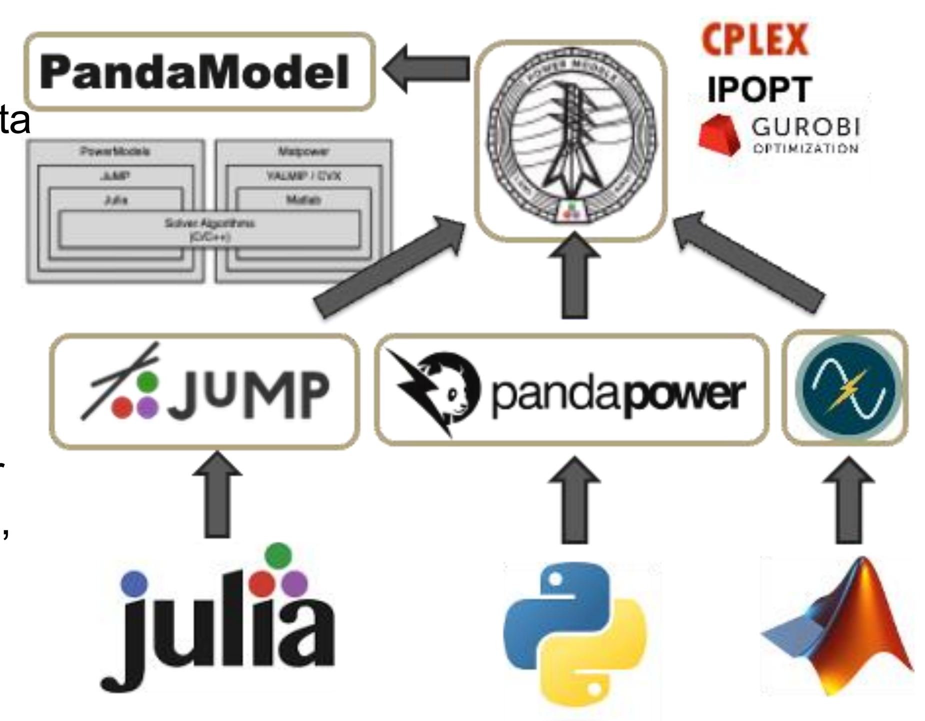


Solvers

- **Optimization Solvers:** Primary focus on IPOPT (Interior Point Method), with support for Gurobi (Branch-and-Bound) and CBC (Branch and Cut).
- **Programming Implementation:** Python-based interface with PandaPower for network modeling, bridged to Julia's PowerModels.jl for optimization capabilities.
- **Mathematical Framework:** Implements full AC OPF formulation with non-linear constraint handling and slack variable mechanisms.
- **Data Exchange:** Supports GO Competition standard formats and MATPOWER data formats for seamless integration.

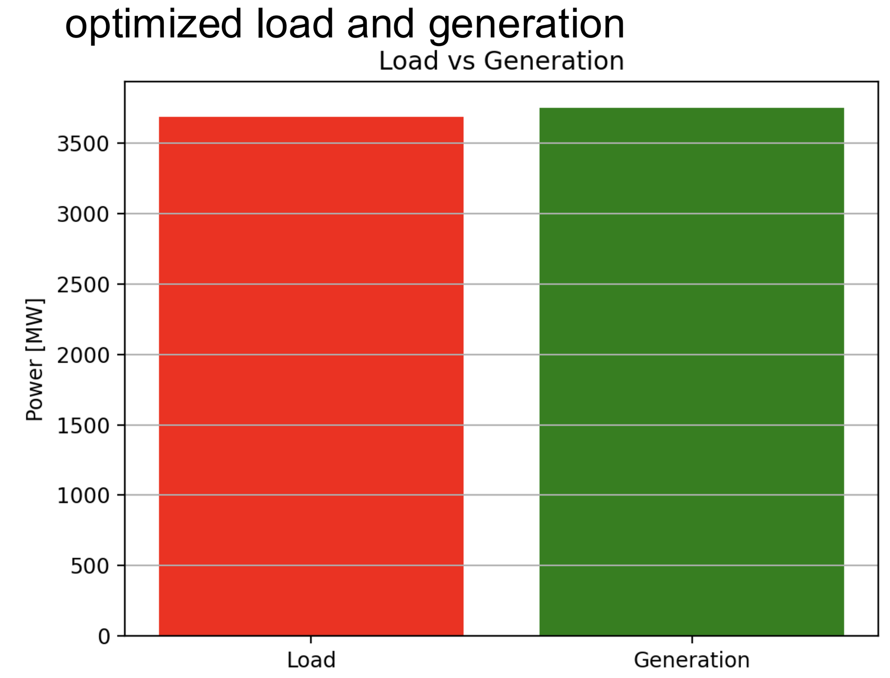
Data Processing

- **Custom Data Pipeline**: Processes GO Competition (.raw) files and cost functions, transforming complex grid data into optimization-ready formats.
- **Integrated Framework**: Connects PandaPower (Python) with PowerModels.jl through PandaModels, enabling seamless data flow between modeling and optimization.
- **Automatic Extraction**: Identifies power system components (buses, generators, lines) and computes electrical parameters based on system requirements
- **Validation System**: Implements error checking to handle data inconsistencies and ensure model integrity



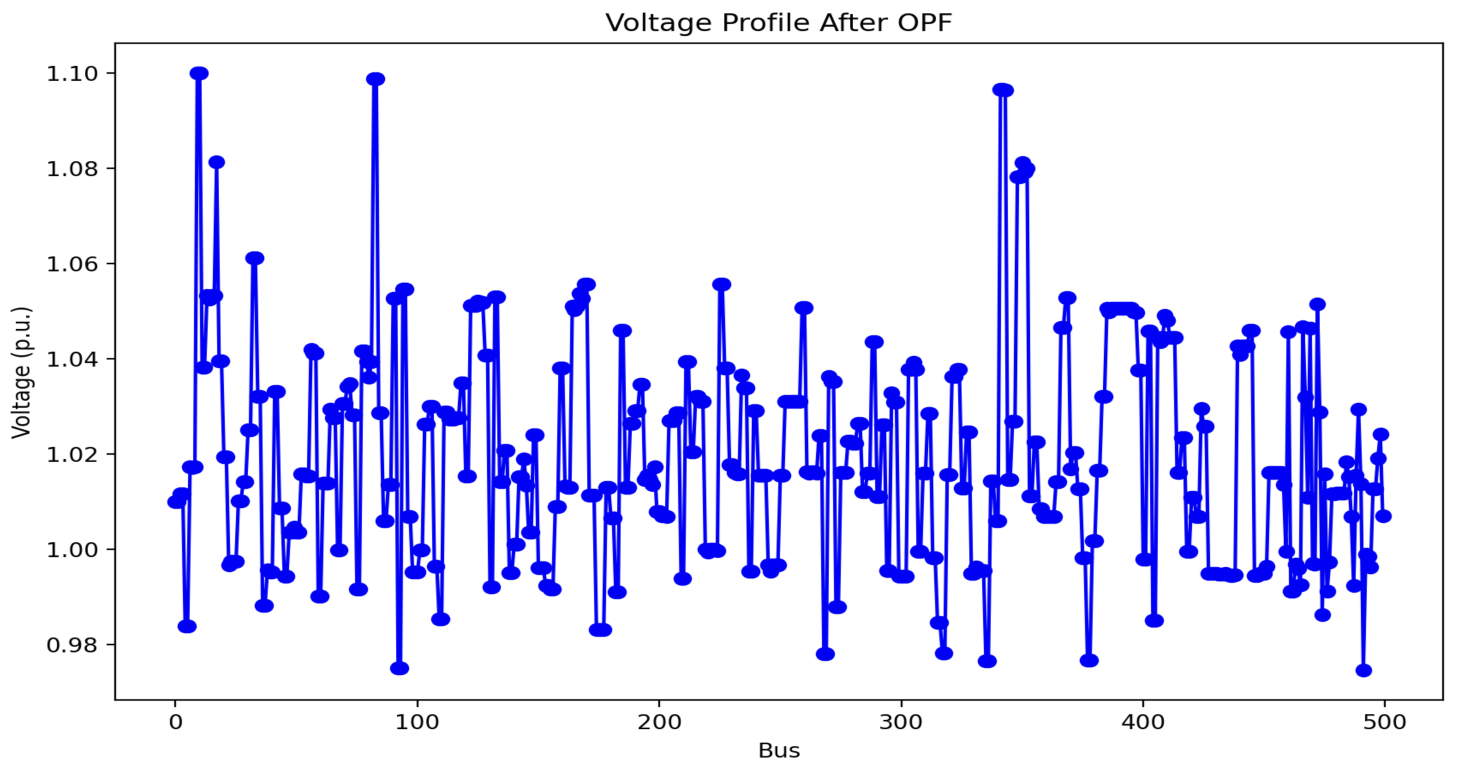
Formulation

- Formulation Goal: Meet network bound constraints and minimize the cost
- Formulated in Python as a pandpower network
- Our formulation takes up to 600 bus cases (buildable), and creates resulting network with optimized load and generation



- Methods used to solve convergence problem:
  - Simplified optimization techniques
  - -Newton-Raphson method
  - Using different solvers
  - Relaxing solver constraints (iterations, bounds, tolerance, etc.)
  - Using DC optimization to approximate starting guesses for AC Optimization
- Most helpful: Using different solvers and testing with multiple networks
  - Bottom lineL differerent networks are optimized better with different methods

Results



- Shown above is a resulting bus voltage profile from an optimized network, with constraints of each bus being met, and no one bus with too high or low of a voltage, suggesting a balanced network(500-bus case example result shown above)

Future Work, References

- **Future Work**:
- 1. Develop and implement algorithms to address contingency-constrained AC Optimal Power Flow (N-1 security-constrained OPF), which ensures that the system can withstand the failure of any single component.
- 2.Design and test advanced algorithms capable of solving the highly nonlinear and non-convex ACOPF problem efficiently.
- 3. Incorporate and preprocess real-world scheduling data provided by GE Vernova to simulate realistic operational scenarios.
- **References**:

- [1]U.S. Department of Energy, Advanced Research Projects Agency–Energy (ARPA-E), "Challenge 1 – Grid Optimization Competition," 2020. [Online]. Available: https://gocompetition.energy.gov/challenges/challenge-1
- [2]U.S. Department of Energy, Advanced Research Projects Agency–Energy (ARPA-E), "SCOPF Problem Formulation: Challenge 1," Apr. 12, 2019. [Online]. Available: https://gocompetition.energy.gov/sites/default/files/SCOPF_Problem_Formulation__Challenge_1_20190412.pdf
- [3]Los Alamos National Laboratory, "GOC3Benchmark.jl: Benchmark algorithm for Challenge 3 of the Grid Optimization Competition," GitHub repository, [Online]. Available: https://github.com/lanl-ansi/GOC3Benchmark.jl

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