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Data-Driven Screening of Network Constraints for Unit Commitment

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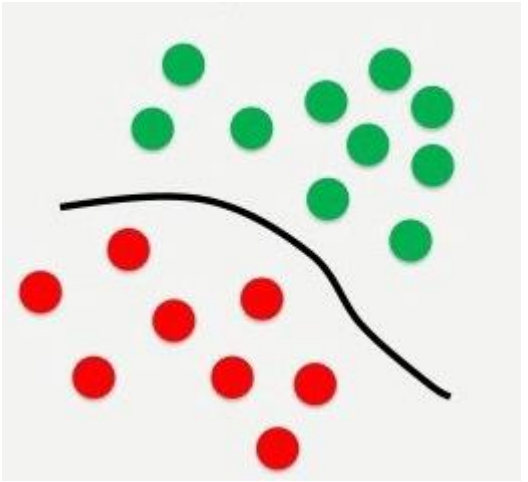
Overview

Unit commitment problem	
Horizon	24h
Objective	Min production cost
Variables	On/off status (binary) Power dispatch
Constraints	Generation = demand Unit technical limits Line technical limits

Classification



AIM

Reduce the computational time of the unit commitment problem by screening out transmission capacity constraints

Screening of network constraints

The unit commitment problem can be generally formulated as follows:

$$\min_{p,u} \quad c^\top p \tag{1a}$$

$$\text{s.t.} \quad \mathbf{1}^\top p = \mathbf{1}^\top d \tag{1b}$$

$$u\underline{p} \leqslant p \leqslant u\overline{p} \tag{1c}$$

$$-\overline{f} \leqslant \mathsf{PTDF}(p-d) \leqslant \overline{f}, \tag{1d}$$

$$u \in \{0,1\} \tag{1e}$$

We compare six different methods to remove some constraints (1d)

Current approaches

Benchmark

- No network constraints are removed (Extremely high time)

Single-bus

- All network constraints are removed (Very fast)

Naive

- It removes line constraints that have not been congested in the past

Constraint generation

- It solves the single-bus UC and iteratively adds violated constraints

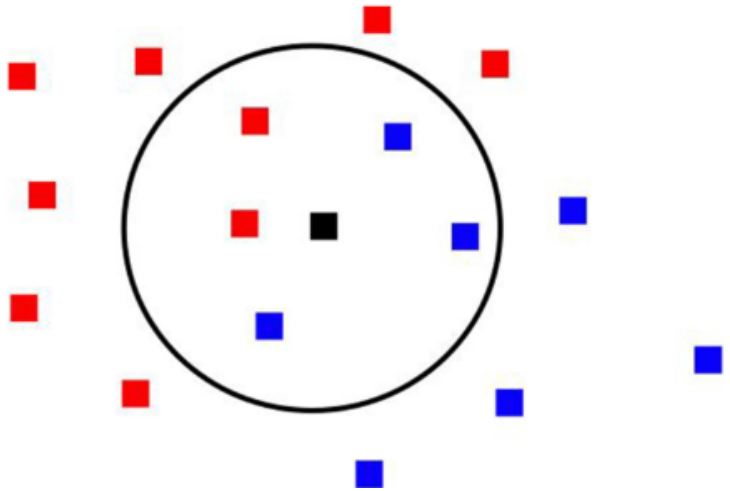
Bounding (Roald and Molzahn 2019)

- It computes the maximum feasible flow through all lines
- It only removes redundant constraints

Proposed data-driven approach

Data-driven method (DD)

- Line congestion is inferred via statistical learning
- No need for solving additional optimization problems
- It removes not only redundant but also inactive constraints
- K-nearest neighbors is used for its simplicity and interpretability
- It can be combined with constraint generation to ensure feasibility



■ → Line is congested
■ → Line is not congested
■ → Line is assumed to be congested

Realistic case study

- Power system in Texas with 2000 buses and 3206 lines
- Electricity demand at each bus is randomly sampled from a uniform distribution between 0 and twice the nominal demand
- 10% of the lines become congested during the year, and the line that most often gets congested reaches its capacity limit during 4000 hours
- 300 instances for training and 60 for testing

Results

Method	Removed(%)	Δcost(%)	Infes(%)	Time(%)
Benchmark	0.0	0.00	0.00	100.0
Single-bus	100.0	-2.17	0.26	0.4
Naive	92.3	0.00	0.00	10.6
Constraint Gen (CG)	98.8	0.00	0.00	8.9
Bounding	54.3	0.00	0.00	64.7
Data-Driven (DD)	98.6	0.04	0.03	2.3
DD+CG	98.5	0.00	0.00	5.3

- Single-bus approach is fast but provides catastrophic results
- Naive removes 92% of constraints and achieves the optimal solution
- ConGen removes a lot of constraints but requires high time
- Bounding only removes 54% of constraints and limits time reduction
- Data-Driven removes most constraints but involves small infeasibilities
- DD+CG recovers the original solution at lowest time

Summary

Method	# Removed	Original solution	Time
Benchmark	🔴	🟢	⏳⏳⏳
Single-bus	🟢	🔴	⏳
Naive	🟠	🟠	⏳
Constraint Gen (CG)	🟢	🟢	⏳⏳
Bounding	🟠	🟢	⏳⏳
Data-Driven (DD)	🟢	🟠	⏳
DD + CG	🟢	🟢	⏳