Data-Driven Screening of Network Constraints for Unit Commitment

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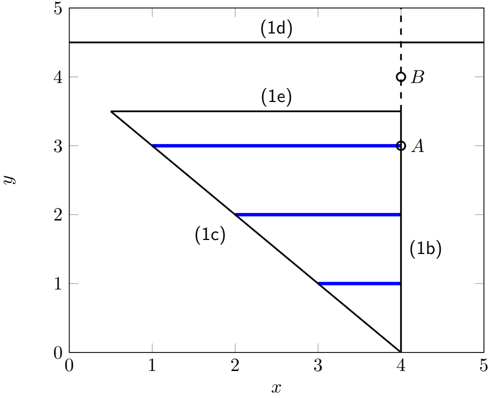
Can we remove constraints to reduce time?

$$
\begin{aligned}
\max_{x\in\mathbb{R},y\in\mathbb{Z}} \quad & x+y && \text{(1a)}\\
\text{s.t.} \quad & x \leqslant 4 && \text{(1b)}\\
& x+y \geqslant 4 && \text{(1c)}\\
& y \leqslant 4.5 && \text{(1d)}\\
& y \leqslant 3.5 && \text{(1e)}
\end{aligned}
$$



- Constraint (1b) is an *active constraint*
- Constraint (1c) is an *inactive constraint*
- Constraint (1d) is a *redundant constraint*
- Constraint (1e) is defined as *quasi-active constraint*

How is the Unit Commitment problem formulated?

- Single-period
- DC power flow
- Thermal units
- Renewable units
- Known demand
- No failures

$$\min_{p_g, u_g, q_n, \epsilon_n} \quad \sum_g c_g p_g + L \sum_n |\epsilon_n| \tag{2a}$$

$$\text{s.t.} \quad q_n + \epsilon_n = \sum_{g: b_g = n} p_g - d_n, \forall n \tag{2b}$$

$$\sum_n q_n = 0 \tag{2c}$$

$$u_g \underline{p}_g \leqslant p_g \leqslant u_g \rho_g \overline{p}_g, \forall g \tag{2d}$$

$$-\overline{f}_l \leqslant \sum_n a_{ln} q_n \leqslant \overline{f}_l, \forall l \tag{2e}$$

$$u_g \in \{0, 1\}, \forall g \tag{2f}$$

We compare 8 different methods to remove constraints (2e)

Which methods can be used to remove constraints?

Benchmark

- No network constraints are removed (Extremely high time)

Single-bus

- All network constraints are removed (Very fast)
- Close-to-optimal solutions in low-congested systems
- Highly suboptimal solutions in general

Perfect information

- Removes all constraints not binding at the optimum
- It cannot be implemented in practice

Naive

- It removes line constraints that have not been congested in the past
- Very conservative (low number of removed constraints)

Constraint generation

- It starts by solving the UC without any network constraint
- Line constraints exceeding their capacity are iteratively added

Which methods can be used to remove constraints?

Roald method (RO)[1]

- Two optimization problems for each line are solved

$$\begin{aligned} \min_{p_g,q_n,d_n} / \max_{p_g,q_n,d_n} \quad & \sum_n a_{l'n} q_n \\ \text{s.t.} \quad & \text{(2b)}, \text{(2c)}, \text{(2d)}, \text{(2e)} \\ & \underline{d}_n \leqslant d_n \leqslant \overline{d}_n, \forall n \end{aligned}$$

- If the objective functions reach the line limit, then its capacity constraints are kept. Otherwise, such constraints are removed.

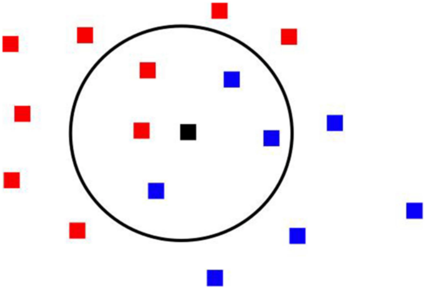
- It only removes redundant constraints

[1] Roald and Molzahn 2019.

Which methods can be used to remove constraints?

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



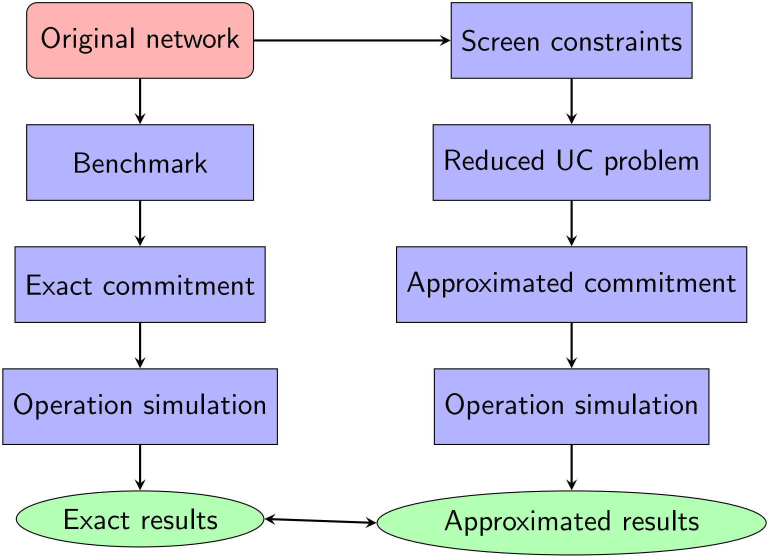
■ → Line is congested
■ → Line is not congested
■ → Line is assumed to be congested

Which methods can be used to remove constraints?

Data-driven + constraint generation (DD+CG)

- Use data to rapidly remove a large number of constraints
- Then iteratively add violated line constraints
- It provides the same solution as BN
- It requires less iterations than CG

What about the results?



Have you tried it on a realistic case study?

- Power system in Texas with 2000 buses and 3206 lines
- Electricity demand at each bus is randomly sampled from uniform distributions 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 training days and 60 test days

What about the 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
Perfect	99.7	-0.22	0.13	1.0
Naive	92.3	0.00	0.00	10.6
ConGen	98.8	0.00	0.00	8.9
Roald	54.3	0.00	0.00	64.7
Data-Driven	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
- Perfect provides suboptimal results due to quasi-active constraints
- Naive removes 92% of constraints and achieves the optimal solution
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Conclusions

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Perfect	🟢	🔴	⌛
Naive	🟠	🟠	⌛
ConGen	🟢	🟢	⌛ ⌛
Roald	🟠	🟢	⌛ ⌛
Data-Driven	🟢	🟠	⌛
DD + CG	🟢	🟢	⌛

Thanks for the attention!

Questions?

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