Cost-driven Screening of Network Constraints for the for the Unit Commitment Problem

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Presented by:
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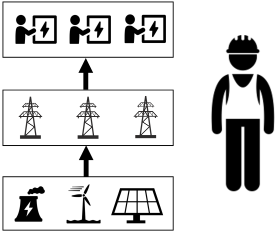
Presentation Outline

- Production level and On/Off status.
- Meeting engineering and physics constraints.
- Clearing day-ahead electricity markets.



Formulation

$$\min_{\mathbf{x}\in\mathbb{R}^n,\, \mathbf{y}\in\{0,1\}^m} \quad f(\mathbf{x},\mathbf{y}) \tag{1}$$

$$g_i(\mathbf{x},\mathbf{y}) \leq 0, \quad \forall i \tag{2}$$

$$h_j(\mathbf{x}) \leq 0, \quad \forall j \tag{3}$$

- Large-scale mixed-integer program.
- NP-hard problem.

$$\min_{u_g, p_g, q_n} \sum_{g \in \mathcal{G}} c_g p_g$$

subject to:

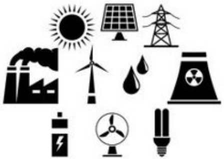
$$q_n = \sum_{g \in \mathcal{G}_n} p_g - d_n, \quad \forall n \in \mathcal{N}$$

$$\sum_{n \in \mathcal{N}} q_n = 0$$

$$u_g \underline{p}_g \leq p_g \leq u_g \overline{p}_g, \quad \forall g \in \mathcal{G}$$

$$-\overline{f}_l \leq \sum_{n \in \mathcal{N}} a_{ln} q_n \leq \overline{f}_l, \quad \forall l \in \mathcal{L}$$

$$u_g \in \{0, 1\}, \quad \forall g \in \mathcal{G}$$



- Simplifications:
  - Single-period.
  - DC power flow.
  - Known net demand.
  - Linear costs.
  - No failures
- Eliminating superfluous transmission constraints.

- Machine learning
- Constraint Generation
- Optimization - Bounding problems - Relaxation of the unit commitment feasible region.

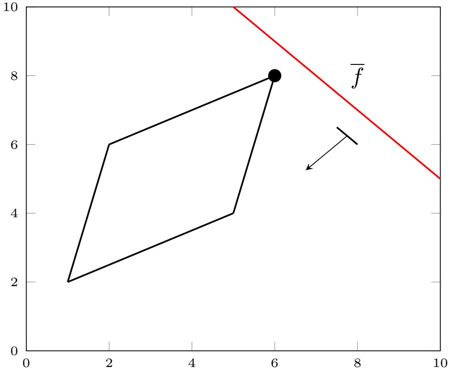


Figure 1: Bounding problem - case 1

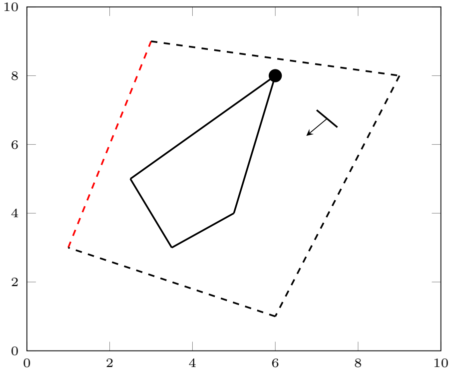


Figure 2: UC problem - case 1

- Machine learning
- Constraint Generation
- Optimization - Bounding problems - Relaxation of the unit commitment feasible region.

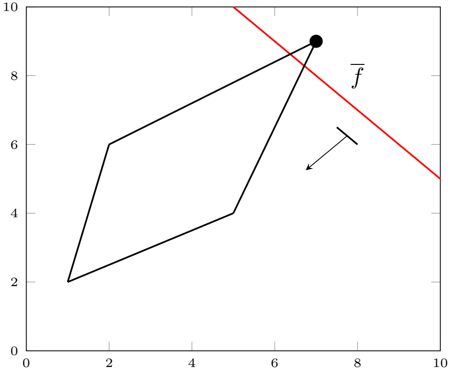


Figure 3: Bounding problem - case 2

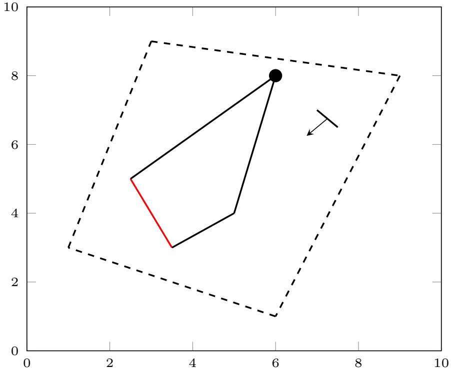


Figure 4: UC problem - case 2

- Economics facts - Constraint with objective function information.
- Constraints not affecting the feasible region.
- Constraints not affecting the minimization of the objective function.

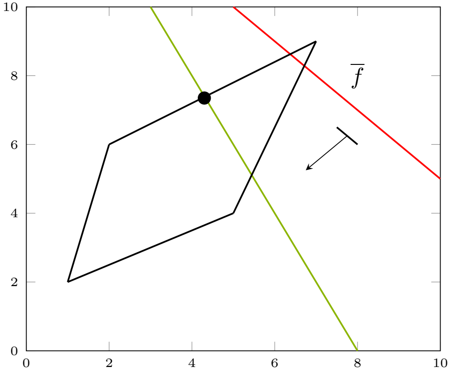


Figure 5: Bounding problem - case 3

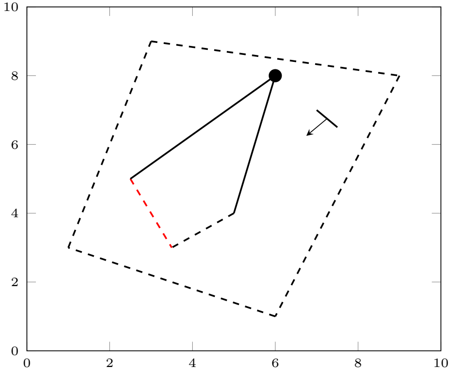


Figure 6: UC problem - case 3

$$\max_{u_g,p_g,d_n,q_n} \; / \; \min_{u_g,p_g,d_n,q_n} \quad f_{l'} = \sum_{n\in\mathcal{N}} a_{l'n} q_n$$

subject to:

$$q_n = \sum_{g\in\mathcal{G}_n} p_g - d_n, \quad \forall n \in \mathcal{N}$$

$$\sum_{n\in\mathcal{N}} q_n = 0$$

$$0 \leq p_g \leq \overline{p}_g, \quad \forall g \in \mathcal{G}$$

$$-\overline{f}_l \leq \sum_{n\in\mathcal{N}} a_{ln} q_n \leq \overline{f}_l, \forall l \in \mathcal{L}, l \neq l',$$

$$\mathbf{d} \in \mathcal{D}$$

L. A. Roald and D. K. Molzahn, "Implied Constraint Satisfaction in Power System optimization: The Impacts of Load Variations," in *2019 57th Annual Allerton Conference on Communication, Control, and Computing (Allerton)*, pp. 308–315, 2019.

The benchmark method used models the net demand as follows:

$\underline{d_n} \leq d_n \leq \overline{d_n}$

Conservative approach

- Non-economical dispatches
- Net demands without spatial correlation

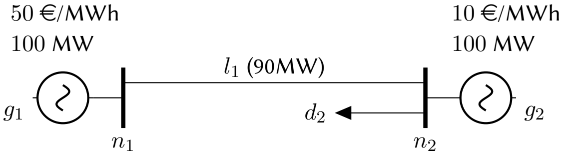
Our proposal

- Impose a maximum cost to the operation of generators.

$$\sum_g c_g p_g \leq \overline{C}$$

- Net demand as convex combination of observed instances.

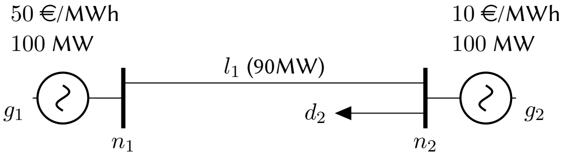
$$d_n = \sum_n \alpha_n \widehat{d}_n, \qquad \sum_n \alpha_n = 1$$



Net Demand $\rightarrow 80 \leq d_2 \leq 120$
Using the benchmark method:

- Minimizing the power flow: $p_1 = 0MW$ – $f_1 = 0MW$
- Maximizing the power flow: $p_1 = 100MW$ – $f_1 = 100MW$ — Non-economical performance!

- The constraint $-90 \leq f_1$ is eliminated.
- The constraint $f_1 \leq 90$ is retained.



Economical information

- $d_2 = 120$, $p_1 = 20$ and $p_2 = 100$
- Total cost $= 2000$€
- We add the following constraint: $50p_1 + 10p_2 \leq 2000$

Using our proposal:

- Minimizing the power flow: $p_1 = 0$ – $f_1 = 0$
- Maximizing the power flow: $p_1 = 30$ – $f_1 = 30$
- The constraint $-90 \leq f_1$ is eliminated.
- The constraint $f_1 \leq 90$ is eliminated.

- **BN**: Benchmark method.
- **UB**: BN + imposing a maximum cost for the operation of the power plants.
- **CC**: Net demand as a convex combination of past instances.
- **CC+UB**: CC + the economical information from the objective function.

Description of the procedure:

1. Use historical information on past unit commitment instances.
2. Determine the set of line capacity constraints that can be removed from the original UC problem.
3. Solve the reduced unit commitment problem.
4. Fix the binary commitment decisions.

All methods obtain the same optimal solution as the original Unit Commitment.

2000-bus system.
8640 hours of unit commitment instances.

- 7200 hours as training set.
- 1440 hours as test set.

Results:

- *UB* does not achieve significant results due to spatial correlations of net nodal demands.
- *CC* gets a meaningful reduction with respect to previous methods.
- *UC+CC* achieves significant results decreasing the retained constraints and the computation burden by 15% and 28%, respectively.

	BN	UB	CC	UB+CC
Retained constraints (%)	33.8	33.0	24.9	18.9
Computational burden (%)	50.7	48.7	35.4	22.5

Presentation Outline

- *We screen out constraints not affecting both the feasibility region and the minimization of the objective function.*
- *Our proposal gets a reduction in terms of retained constraints and computational burden by 15% and 28%, respectively.*
- *We reduce the computational time of the original Unit Commitment problem up to 77.5%.*

Thank You!
Questions?

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