High Performance Computing vs. Heuristic
A performance benchmark for optimization problems with linear power flows
by Karl-Kiên Cao & Manuel Wetzel

Background: Solving Energy System Models is associated with high computing times

Key results:
- Speed-up factor: 10
- Heuristic outperforms parallel solver for medium-sized models

Outlook
- Benchmarks for large-scale models
- New PIPS-IPM++ version: more stable, MIP
High Performance Computing vs. Heuristic

A performance benchmark for optimization problems with linear power flows

Karl-Kiên Cao & Manuel Wetzel
MOTIVATION
Energy System Transition

today
What needs to be modeled
What can be modeled

OPF / TEP studies

Energy System Optimization

Number of time steps
Number of regions
Number of technologies
What can be modeled

OPF / TEP studies

Energy System Optimization

Number of time steps

Number of regions

Number of technologies
Solving large optimization models

\[
\begin{align*}
\text{min} & \quad c^T x \\
\text{s.t.:} & \quad Ax \leq b \\
& \quad x \geq 0
\end{align*}
\]
Solving large optimization models

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\end{align*}
\]
Solving large optimization models

\[ \text{min } c^T x \]
\[ \text{s.t.: } \]
\[ Ax \leq b \]
\[ x \geq 0 \]

Linking constraint (e.g. fuel budget)

Linking variable (e.g. capacity expansion)

Linking variables & constraints (power flow constraints)
Objective

How to deal with increasing computing times?

Speed-up approaches (parallelization)
Objective

How to deal with increasing computing times?

Speed-up approaches (parallelization)

Which approach performs better? High performance computing or heuristics?
METHODOLOGY
## Model factsheet

<table>
<thead>
<tr>
<th>Model type</th>
<th>Energy System Optimization Model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Multi-regional Economic Dispatch</td>
</tr>
<tr>
<td></td>
<td>• (Transmission and storage expansion planning)</td>
</tr>
<tr>
<td>Number of regions (zones)</td>
<td>120</td>
</tr>
<tr>
<td>Number of time steps</td>
<td>8760</td>
</tr>
<tr>
<td>Scope</td>
<td>Scenario of the German power system</td>
</tr>
<tr>
<td>4 Model instances and reference computing times</td>
<td>Cap.-constrained transport</td>
</tr>
<tr>
<td></td>
<td>DC power flow</td>
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<tr>
<td></td>
<td>Dispatch 15 min</td>
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<tr>
<td></td>
<td>Expansion 75 min</td>
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<tr>
<td></td>
<td>20 min</td>
</tr>
<tr>
<td></td>
<td>127 min</td>
</tr>
</tbody>
</table>
Approach I: Heuristics

I: Storage levels

II: Hourly time steps

Averaged time steps

Time horizon

Parallel solving with comm. solver on shared memory
Approach II: PIPS-IPM++

Model annotation

Globally linking variables

Independent blocks

Globally linking constraints
Approach II: PIPS-IPM++

Parallel solving on distributed memory
RESULTS
Heuristics

@ 1 computing node with up to 72 parallel threads (2x18 CPU cores, hyperthreading)
Heuristics

Reachable speed-up factor: 10 across all model instances
PIPS-IPM++

@ 7 computing nodes with up to 36 parallel threads (2x18 CPU cores)
PIPS-IPM++

Reachable speed-up factor: 10
only for one model instance
CONCLUSIONS
Discussion

• Heuristic beat PIPS-IPM++
  – Faster and more stable across model instances

• But
  – Accuracy loss: up to 3% deviation of objective value
  – Intermediate-sized model (reference computing times <24h)
  – Memory may become also a bottleneck
Conclusion & Outlook

• Energy System Energy Optimization: more complex and thus computational heavy
• 2 approaches exploiting parallelization
• Observed speed-up: 10
• More stable versions of PIPS-IPM++
  ▪ Large models: >48 h reference computing time
  ▪ + Neural Networks → Mixed Integer Programs
THANK YOU!

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