Polskie Sieci Elektroenergetyczne

Optimal Topology Switching

Innovation research journey for PSE

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Optimal Topology Switching

Innovation research journey

- Different approaches
  - MILP OTS
  - Linear OTS
  - GLODF
- Innovation tricks
  - OTS linear ranking
  - N-1 criterion: Close to be overloaded
  - Daily OTS: multi-intertemporal optimization vs heuristic idea

Optimal Topology Switching

Innovation research journey – different approaches

Different approaches

MILP OTS

- Directly optimal calculation
  - Accurate
  - Only one solution
- Computational time
  - N-1 criterion

Linear OTS

- Partial evaluation of all the flows
- Iteratively building a ranking
- Accurate calculation for the most promising topological actions
- Fast and accurate
- Computational time
  - European network

GLODF

- All the flows evaluation
- Two parts: matrix creation and multiplication
  - The matrix creation can be preprocessed.
  - The matrix multiplication is much faster for all

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Innovation research journey – linear OTS

Linear OTS formulation and duals

$$
\begin{aligned}
\min_{\boldsymbol{\theta},\mathbf{f_v^{br}},\mathbf{f_v^{sb}},\boldsymbol{Y}} \quad & \sum_{br\in\mathcal{BR}} \mathbf{f_v^{br}} + \sum_{sb\in\mathcal{SB}} \mathbf{f_v^{sb}} \\
(\lambda_1,\lambda_2): \quad & |B^{br}\cdot\boldsymbol{\theta} + f^{br}_{PST}| \le f^{br}_{max} + \mathbf{f_v^{br}} \\
(\delta_1,\delta_2): \quad & |\mathbf{f} - B^{sb}\cdot\boldsymbol{\theta} - f^{sb}_{PST}| \le M\cdot(1-\boldsymbol{Y}) \\
(\mu_1,\mu_2): \quad & |\mathbf{f}| \le f^{sb}_{max}\cdot\boldsymbol{Y} + \mathbf{f_v^{sb}} \\
(\beta): \quad & \boldsymbol{P^{inj}} - A\cdot B\cdot\boldsymbol{\theta} - f^{inj}_{PST} = 0 \\
(\gamma): \quad & \boldsymbol{P^{inj}} = P^{inj}_{max} \\
(\kappa): \quad & \mathbf{f_v^{sb}} \le \boldsymbol{Y}\cdot M \\
(\alpha): \quad & \boldsymbol{Y} = Y_{ta}
\end{aligned}
$$

Glossary

$\mathcal{BR}$ – set of all branches except of switchable branches
$\mathcal{SB}$ – set of all switchable branches (topological actions)
$\mathbf{f_v^{br}}$ – decision variable: vector of flows above flow limit per branch in set $\mathcal{BR}$
$\mathbf{f_v^{sb}}$ – decision variable: vector of flows above flow limit per branch in set $\mathcal{SB}$
$\boldsymbol{Y}$ – decision variable: vector of binary variables with branch status, defined only for switchable branches
Y_{ta} – vector of branch status for topological action
ta – topological action combination
M – big value defined for switchable branches
B – admittance matrix
B – $B^{br} \cup B^{sb}$
A – incidence matrix
$\boldsymbol{\theta}$ – decision variable: voltage angle
$\mathbf{f}$ – decision variable: flow
f^{br}_{max} – flow limit per branch in set $\mathcal{BR}$
f^{sb}_{max} – flow limit per branch in set $\mathcal{SB}$
f^{sb}_{PST} – phase shifter per branch in set $\mathcal{BR}$
f^{br}_{PST} – phase shifter per branch in set $\mathcal{SB}$
$\boldsymbol{P^{inj}}$ – decision variable: vector of injections defined as total generation minus demand per node
P^{inj}_{max} – vector of injections with maximum generation
f^{inj}_{PST} – vector of injections of phase shifters

Optimal Topology Switching

Innovation research journey – linear OTS

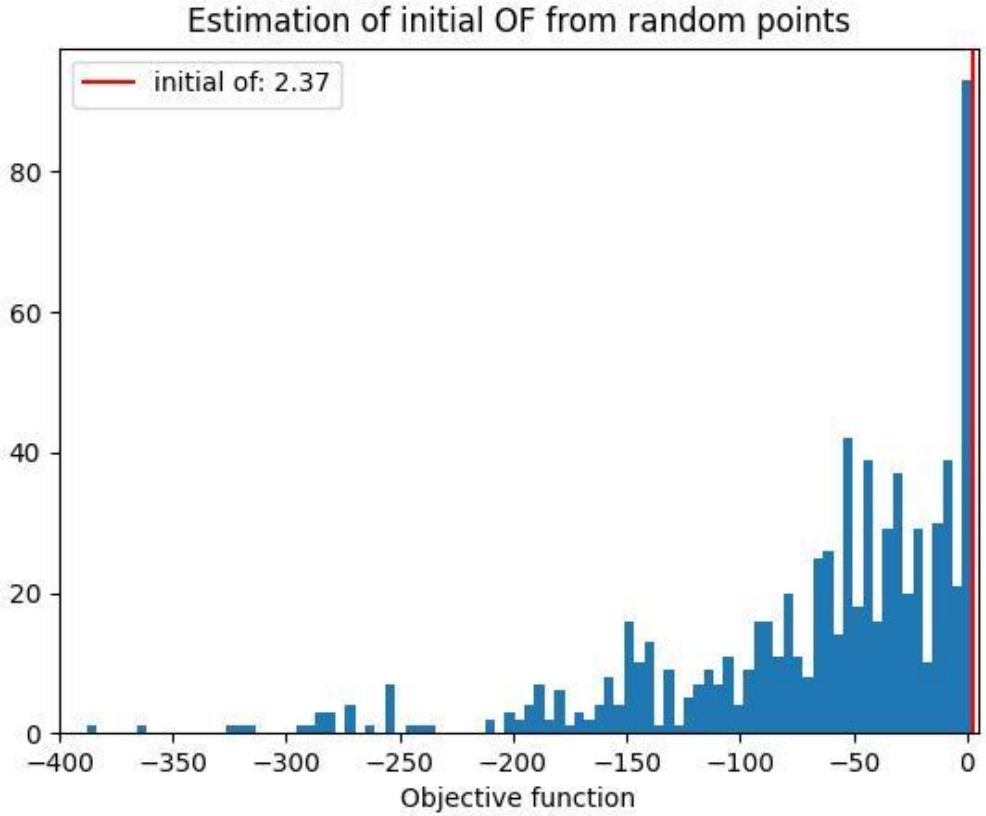
Linear OTS formulation and duals

The duals represent an overestimation of the real profit

If the dual overestimation is really promising, then the topological action can be good or bad for relieving the congestions
If the dual overestimation is bad one, then it is ensured that the topological action is not good for relieving congestions
The dual overestimation may not be accurate enough to provide the topological actions

The duals are extracted from the Linear OTS (fast LP optimization problem)

It is possible to simulate fast several topological actions



Optimal Topology Switching

Innovation research journey – linear OTS

- Linear OTS formulation and duals

Estimation of objective function with duals

$$OF_{ta,ta^*}^{estimated} = OF_{ta^*} + \alpha_{ta^*} \cdot (Y_{ta} - Y_{ta^*})$$

$$OF_{ta}^{k,estimated} = \max\left(OF_{ta}^{(k-1),estimated}, \max_{ta^* \in sta_k}(OF_{ta,ta^*}^{estimated})\right)$$

Glossary

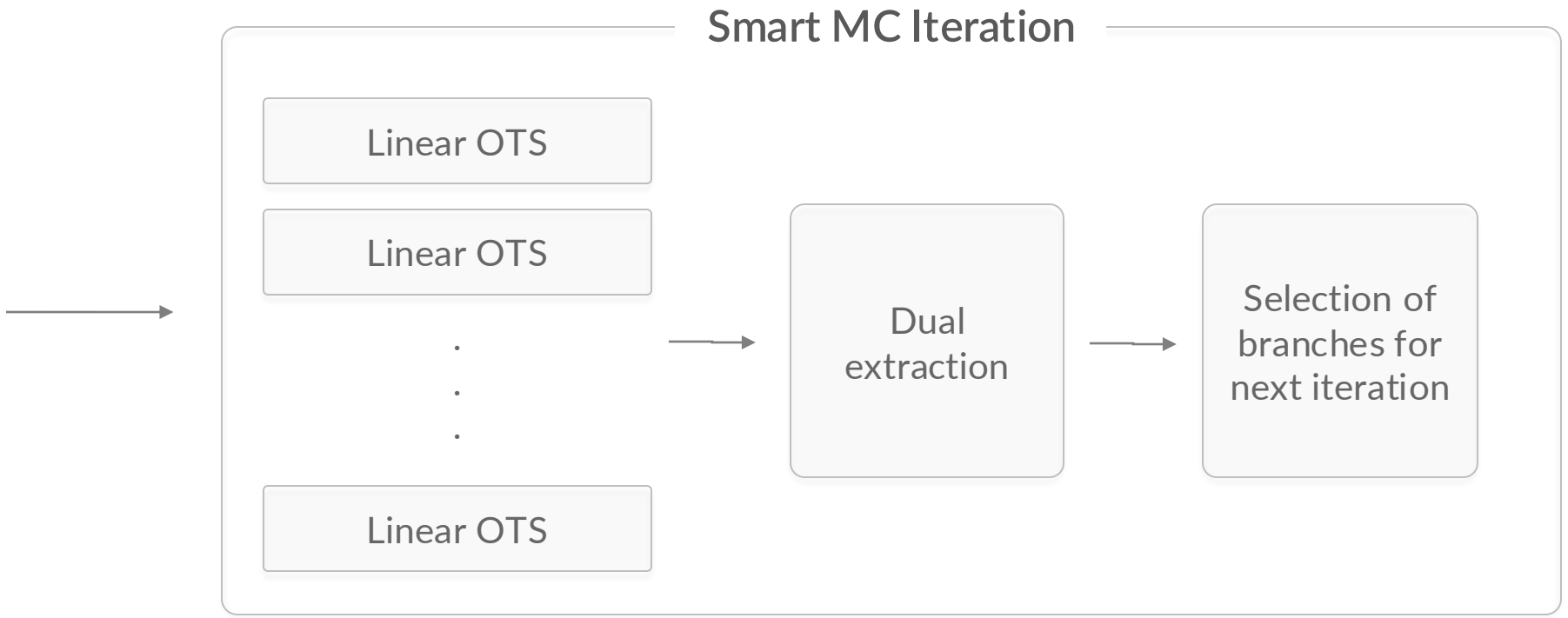
ta – topological action combination
ta* – simulated ta (fixed in linear OTS)
TA – set of all topological action combinations
k – iteration index
$\mathbf{sta_k}$ – set of simulated ta in iteration k
$\mathbf{OF_{ta}}$ – objective value of the system for ta
$\mathbf{OF_{ta,ta^*}^{estimated}}$ – estimated objective value of ta from the system for ta^*
$\boldsymbol{\alpha_{ta}}$ – vector of dual variables for ta
$\mathbf{Y_{ta}}$ – vector of binary status of switchable branches for ta
$\mathbf{OF_{ta}^{k,estimated}}$ – final value of estimated objective function for ta and iteration k

Optimal Topology Switching

Innovation research journey – linear OTS

Linear OTS algorithm

	estimated_of	random_point
2	-104.0129	[1, 2, 10]
3	-102.8529	[2, 10, 15]
4	-102.7029	[2, 9, 10]
5	-102.3329	[2, 8, 10]
6	-101.8529	[1, 10, 15]
7	-101.7029	[1, 9, 10]
8	-101.3329	[1, 8, 10]
9	-100.5429	[9, 10, 15]
10	-100.1729	[8, 10, 15]
11	-100.0229	[8, 9, 10]
12	-97.6629	[2, 5, 10]
13	-96.6629	[1, 5, 10]
14	-95.5029	[5, 10, 15]
15	-95.3829	[2, 7, 10]
16	-95.3829	[2, 4, 10]



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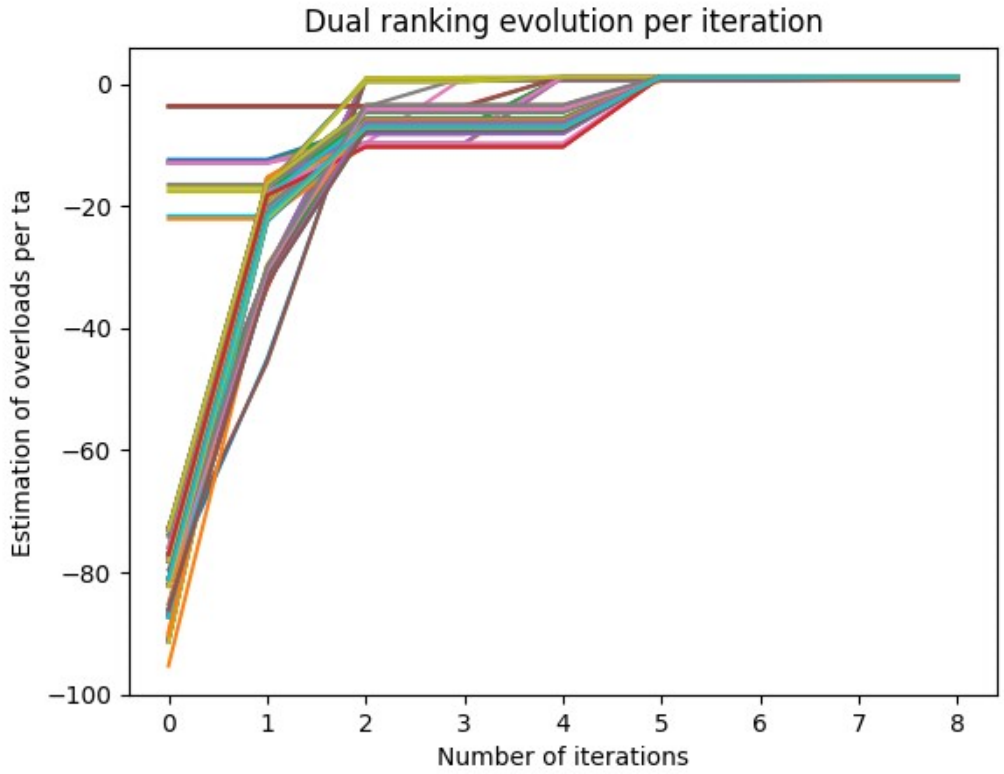
Innovation research journey – linear OTS

- Linear OTS ranking

Stopping criterion

When the top 10 ta from the dual ranking are exact values, then we stop the Smart Monte Carlo



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Innovation research journey – linear OTS

- Linear OTS ranking – results

	Smart Monte Carlo [no TA]	GLODF method [no TA]
case 14 - 1350 TA	120 (9%)	1350 (100%)
case 118 - 17 391 TA	3990 (23%)	17 391 (100%)

SMART Monte Carlo doesn't compute all the topological actions to find the optimal combination

Optimal Topology Switching

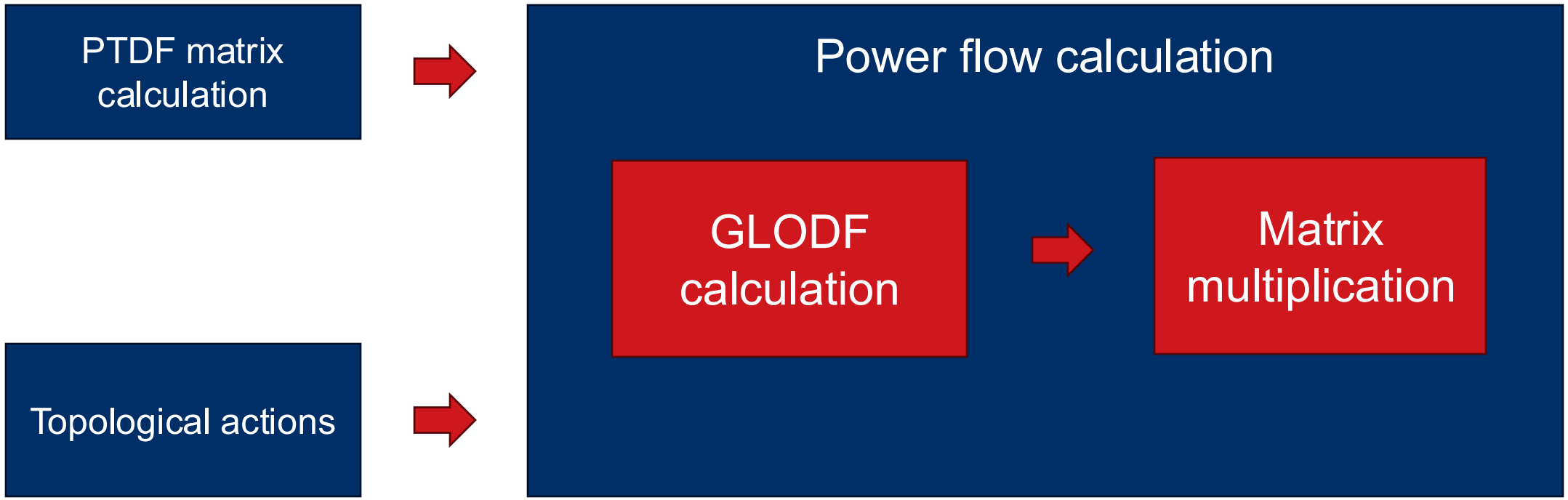
Innovation research journey – GLODF

- GLODF
  - Overview
  - GLODF: N-1 criteria

Optimal Topology Switching

Innovation research journey – GLODF

- GLODF: overview



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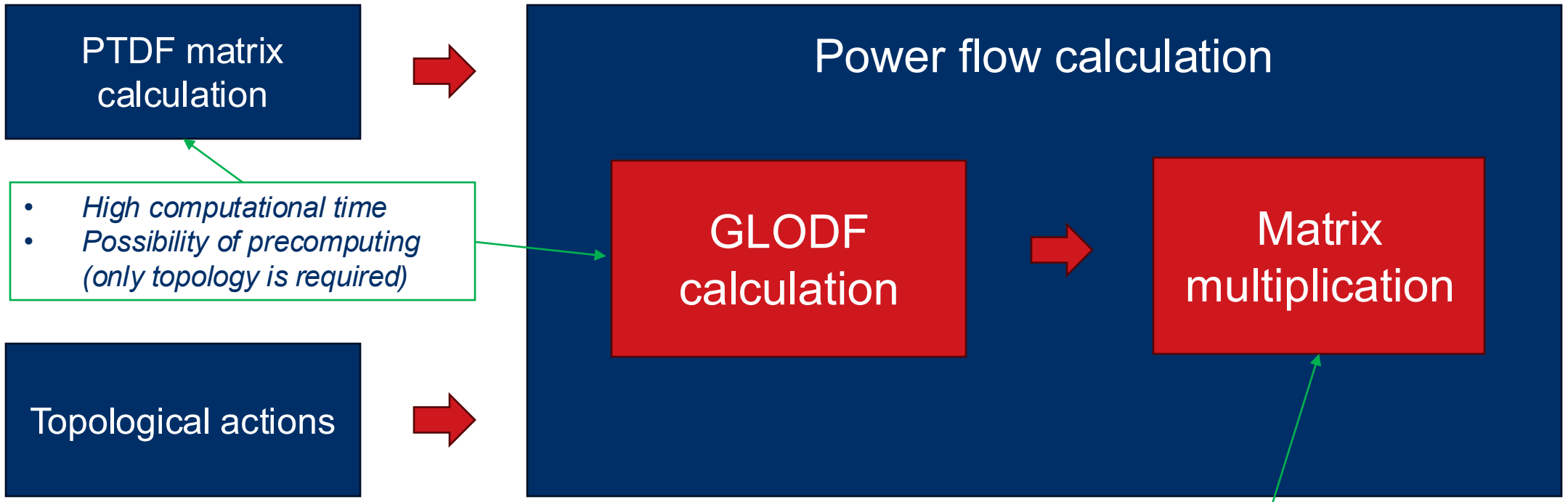
Innovation research journey – GLODF

GLODF: overview



Optimal Topology Switching

Innovation research journey – N-1 criteria

- GLODF: N-1 criteria

Theoretical approach

- Evaluate all the contingencies with GLODF (~400 contingencies)

Optimal Topology Switching

Innovation research journey – N-1 criteria

- GLODF: N-1 criteria

Practical approach

- *"Only the contingencies with branches close to be overloaded contribute to the reducing the overload"*
- Evaluate only the contingencies close to be overloaded (90-95%)
  - **21 contingencies**
- NOTE: The less overloaded system, the better computes. Only for applications with small congestions
- MILP generalization: lazy constraints or iterative evaluating and adding

Optimal Topology Switching

Innovation research journey – daily OTS

- Daily OTS: multi-intertemporal optimization vs heuristic idea

Multi-intertemporal optimization	Heuristic idea
• One MILP optimization that consider different timestamps links into one • Allowing intertemporal constraints • Ideal and elegant solution • High computational time	• Fast application for operational purposes. • Only performed independently OTS per each hour. • Aggregated the daily results based on some scores

Optimal Topology Switching

Innovation research journey – daily OTS

- Daily OTS

Heuristic idea

- Fast application for operational purposes.
- Only performed independently OTS per each hour.
- Aggregated the daily results based on some scores

- Final selection intention
  - To add some scores per hours
  - More importance to the ta in most of the hours
  - More importance to the ta in the elements most overloaded
  - No interest in the hours without overloads
- Possible solution
  - To weigh the hours depending on their share on the sum of overloads over the day

Thank you for your attention!

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