



Topology Optimization @ Elia Group

A GPU-native Approach on Tackling Grid Topology
Optimization

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Agenda

Motivation

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- Development
- 1) GPU-based DC load flow solver
 - 2) From first optimization results to operation
 - 3) Collaboration across TSOs and Research
-

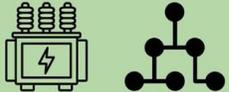
Resources



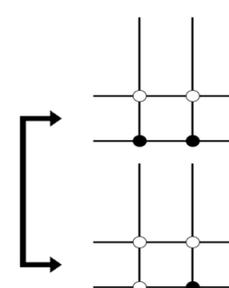
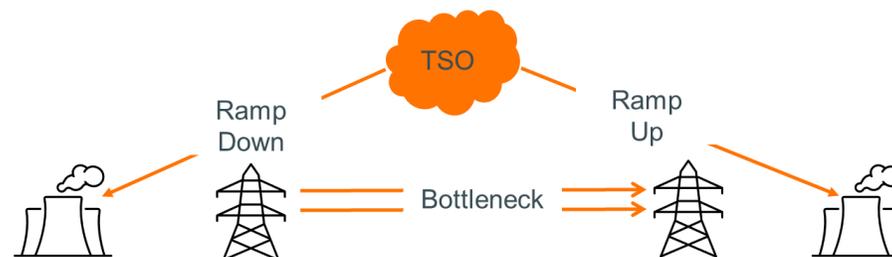
Motivation – Building a scalable, non-costly remedial action optimizer



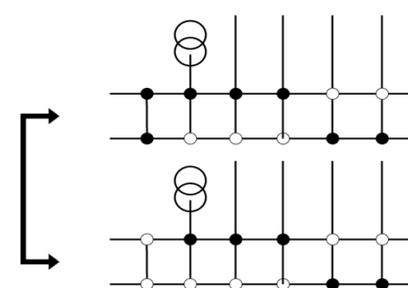
Redispatch generation
Ex: asking a nearby power plant to produce more than planned.
Used frequently
COSTLY



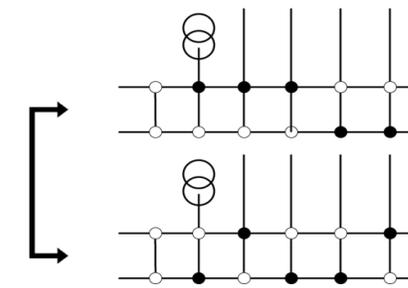
Change Topology
Ex: Disconnecting a powerline
Hard to find
CHEAP



Transmission line switching



Busbar splitting
 (e.g opening busbar couplers)

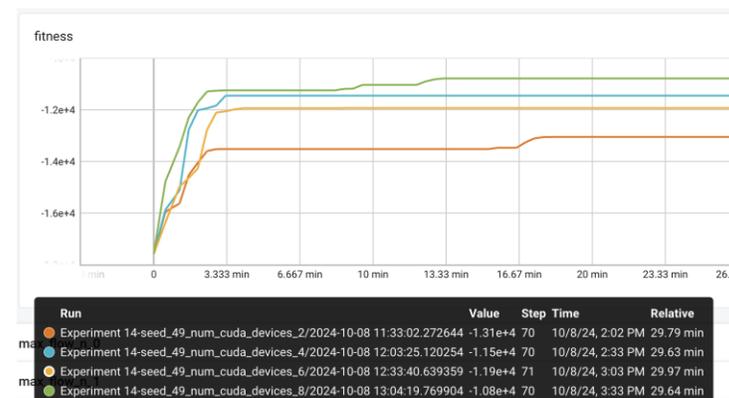
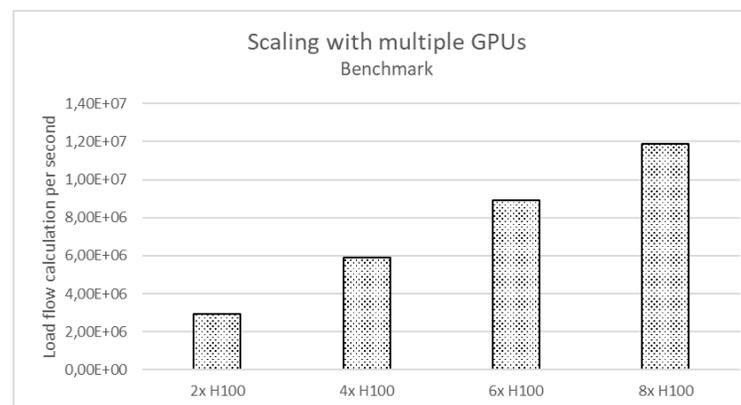
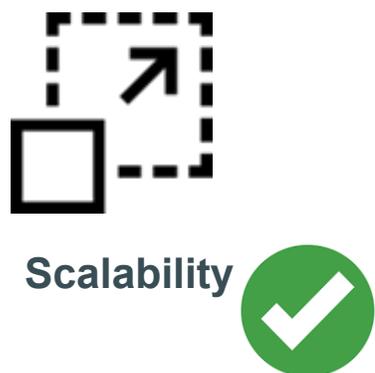
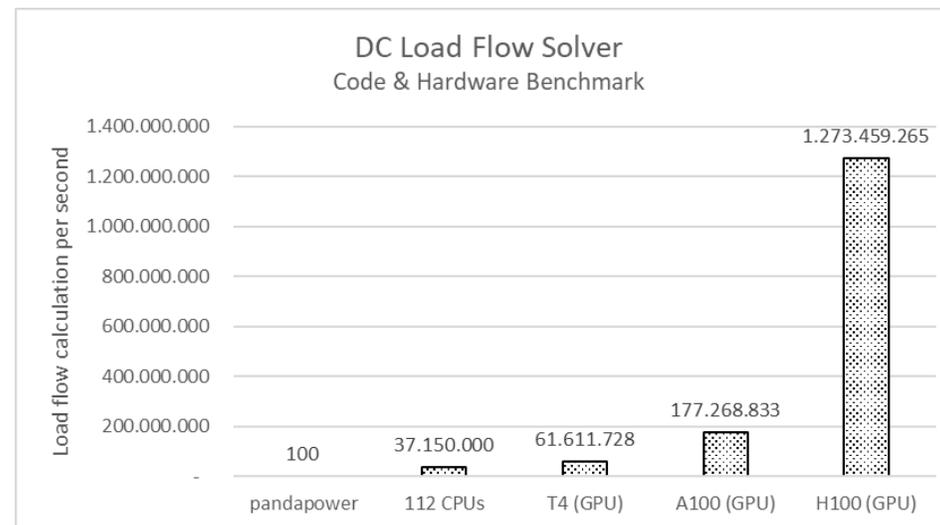
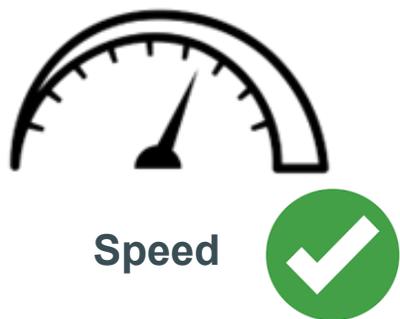


Busbar reassignments

+ PST optimization + reconnections in R&D

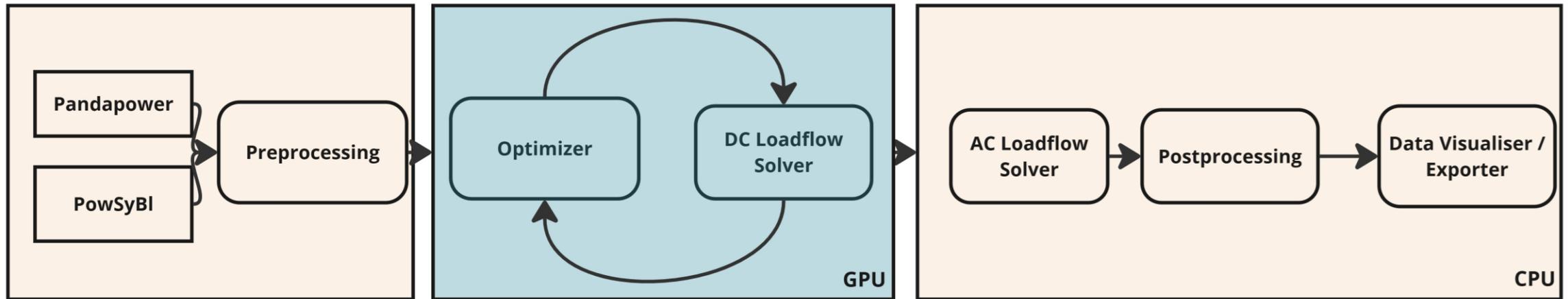


Development 1 - GPU-based DC load flow solver



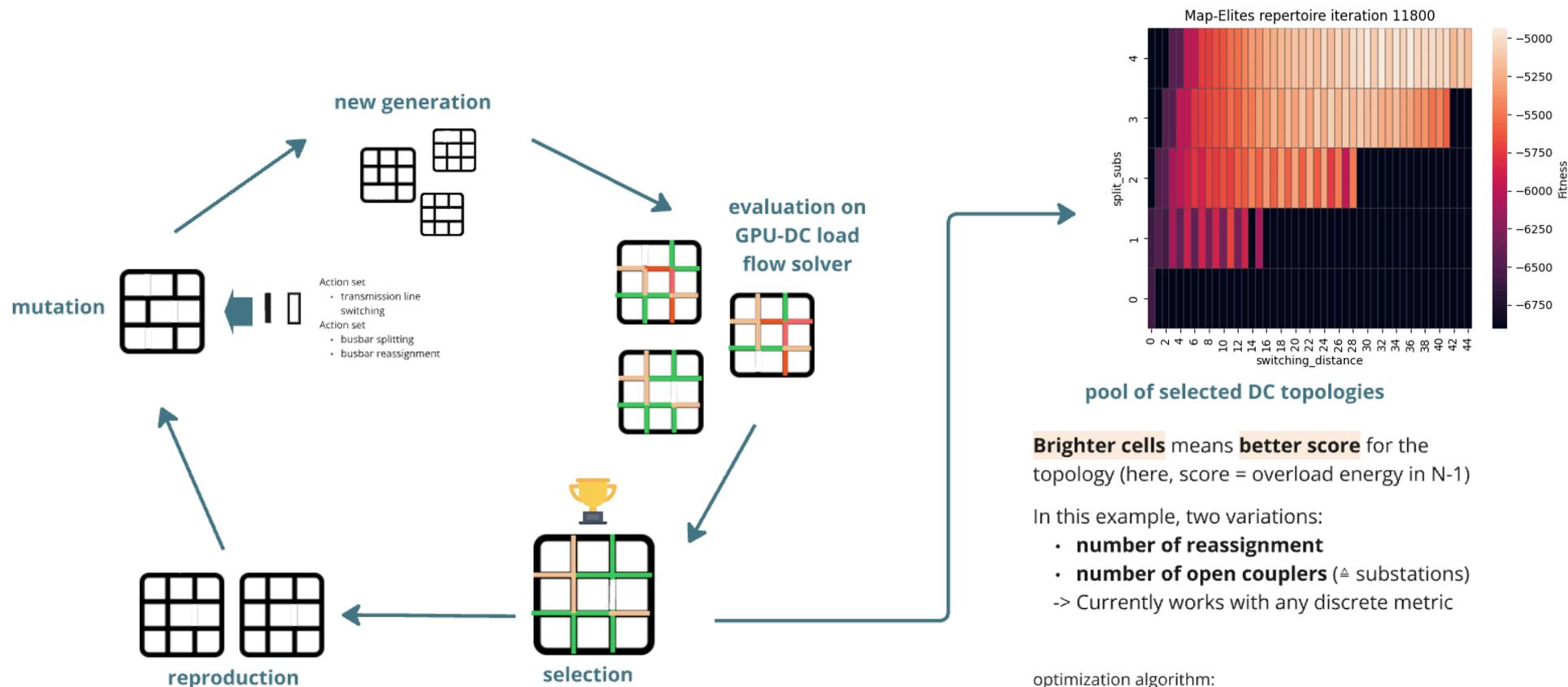
Development 2 - From first optimization results to operation

High Level Architecture



Development 2 - From first optimization results to operation

How does the optimization work?



pool of selected DC topologies

Brighter cells means **better score** for the topology (here, score = overload energy in N-1)

In this example, two variations:

- **number of reassignment**
 - **number of open couplers** (≠ substations)
- > Currently works with any discrete metric

optimization algorithm:

MAP-Elites = Multi-dimensional Archive of Phenotypic Elites



Development 2 - From first optimization results to operation

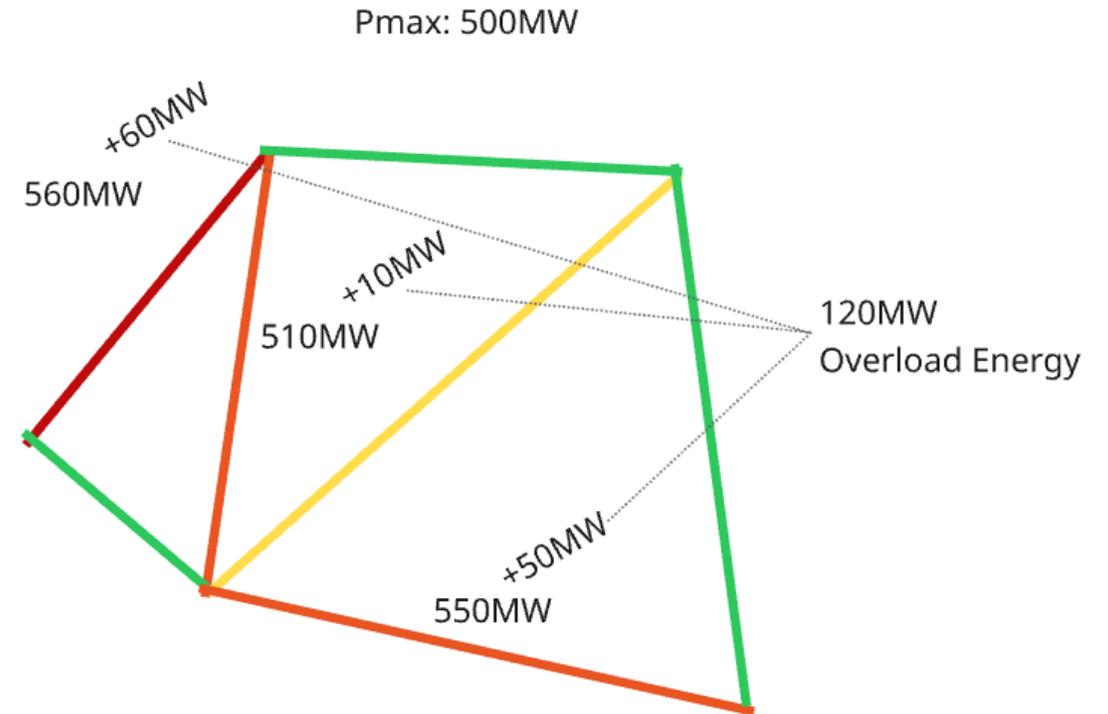
What are we optimizing?

Overload energy:

- 1.) Select one branch
- 2.) Calculate the overload for all N-1 cases and store the case with the highest overload for the selected branch

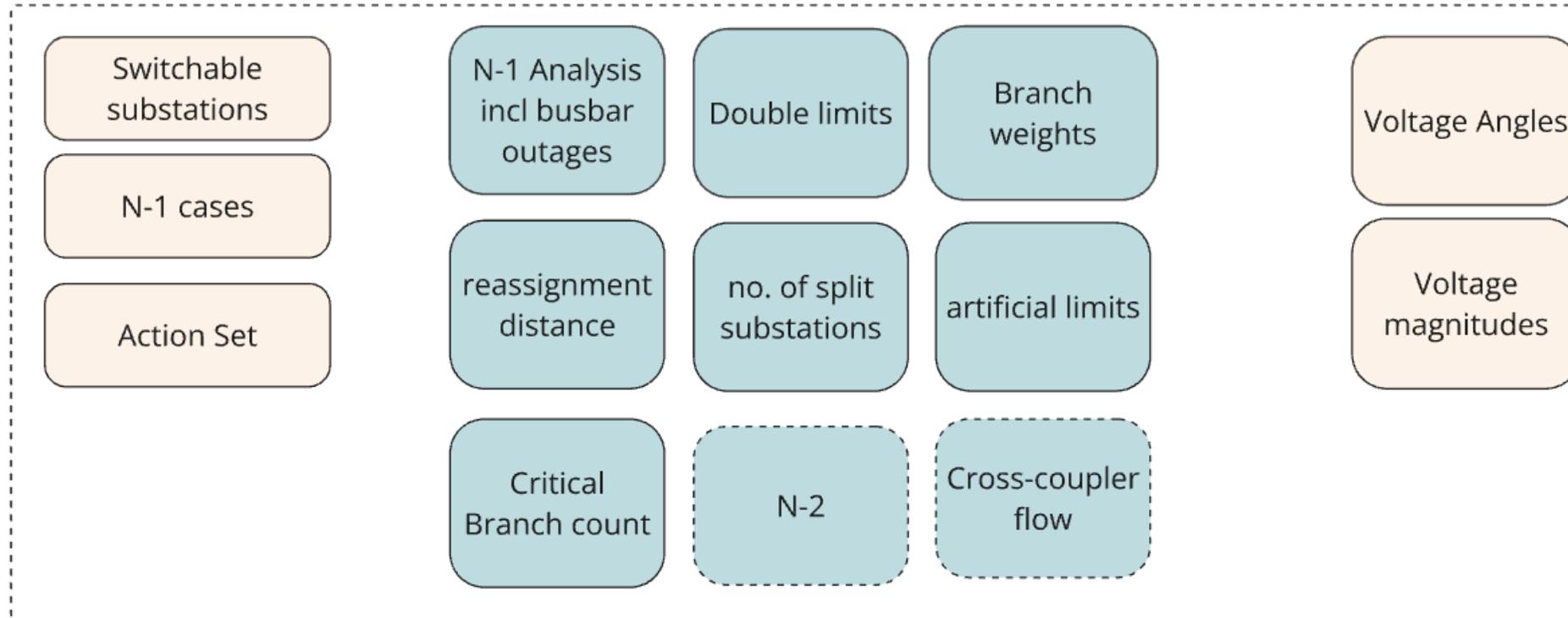
Repeat step 1 & 2 for all branches

- 3.) Sum all overloads = Overload Energy



Development 2 - From first optimization results to operation

Adding Operator Constraints



Development 2 - From first optimization results to operation

Optimizations running in operation as part of MCCS

Strategy 1 (ID 853 AC)		Overload Energy		Switching Distance		Open Couplers in		Disconnected Lines																	
		44.76 MW		7		[Yellow Bar] [Yellow Bar] [Yellow Bar]		-																	
		00:30	01:30	02:30	03:30	04:30	05:30	06:30	07:30	08:30	09:30	10:30	11:30	12:30	13:30	14:30	15:30	16:30	17:30	18:30	19:30	20:30	21:30	22:30	23:30
Overloads		-	-	-	-	-	-	-	-	119 %	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CB:	[Yellow Bar]	-	-	-	-	-	-	-	-	119 %	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO:	[Yellow Bar]	-	-	-	-	-	-	-	-	119 %	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CB:	[Yellow Bar]	-	-	-	-	-	-	-	-	101 %	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO:	[Yellow Bar]	-	-	-	-	-	-	-	-	101 %	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CB:	[Yellow Bar]	-	-	-	-	-	-	-	-	97 %	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO:	[Yellow Bar]	-	-	-	-	-	-	-	-	97 %	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CB:	[Yellow Bar]	-	-	-	-	-	-	-	-	97 %	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO:	[Yellow Bar]	-	-	-	-	-	-	-	-	97 %	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CB:	[Yellow Bar]	-	-	-	-	-	-	-	-	95 %	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO:	[Yellow Bar]	-	-	-	-	-	-	-	-	95 %	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Strategy 2 (ID 770 AC)		Overload Energy		Switching Distance		Open Couplers in		Disconnected Lines																	
		802.21 MW		-		-		-																	
		00:30	01:30	02:30	03:30	04:30	05:30	06:30	07:30	08:30	09:30	10:30	11:30	12:30	13:30	14:30	15:30	16:30	17:30	18:30	19:30	20:30	21:30	22:30	23:30
Overloads		-	-	-	-	-	-	-	-	146 %	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CB:	[Yellow Bar]	-	-	-	-	-	-	-	-	146 %	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO:	[Yellow Bar]	-	-	-	-	-	-	-	-	146 %	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CB:	[Yellow Bar]	-	-	-	-	-	-	-	-	146 %	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO:	[Yellow Bar]	-	-	-	-	-	-	-	-	146 %	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CB:	[Yellow Bar]	-	-	-	-	-	-	-	-	138 %	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO:	[Yellow Bar]	-	-	-	-	-	-	-	-	138 %	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CB:	[Yellow Bar]	-	-	-	-	-	-	-	-	138 %	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO:	[Yellow Bar]	-	-	-	-	-	-	-	-	138 %	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CB:	[Yellow Bar]	-	-	-	-	-	-	-	-	129 %	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO:	[Yellow Bar]	-	-	-	-	-	-	-	-	129 %	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Development 3 - Collaboration across TSOs and Research



Development 3 - Collaboration across TSOs and Research

Further research: DC+

- Idea started to form during literature review and exchanging with other TSOs and research institutions -> foster open-source collaboration on accelerated load flow solvers
- **Idea:** Reformulate AC load flow solver approximation in DC but also include voltages -> DC+
- Completely new math theory (early development / not published)
- Usable inside MILP for approximating N-1 constraints or timesteps (e.g. VoltControl, Redispatch)
- Usable inside topology framework as load flow solver
- Pretty accurate on some grids (ca 3 digits precision against AC)
- **Major challenge:** risky but promising

Partners:



Resources



[Accelerated DC loadflow solver for topology optimization \(GPU DC Solver + Optimizer\)](#)

SOON

Send us a mail:
toop@eliagroup.eu

Operator Constraints
Paper



[Voltage-sensitive distribution factors for contingency analysis and topology optimization \(DC+\)](#)

SOON



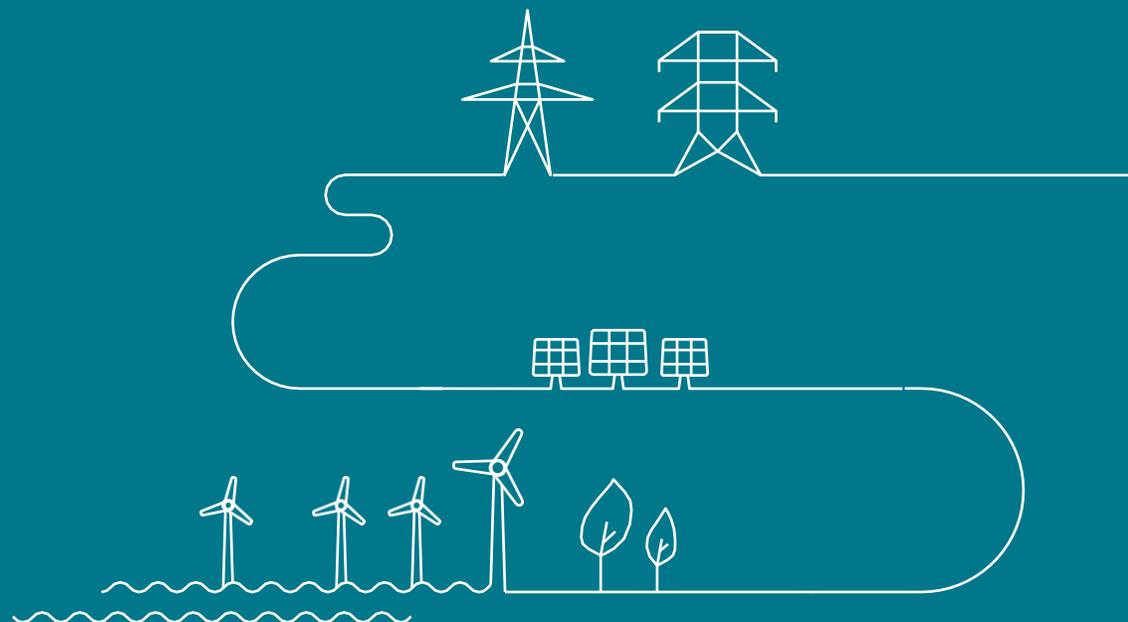
[Topology Optimizer Source Code](#)



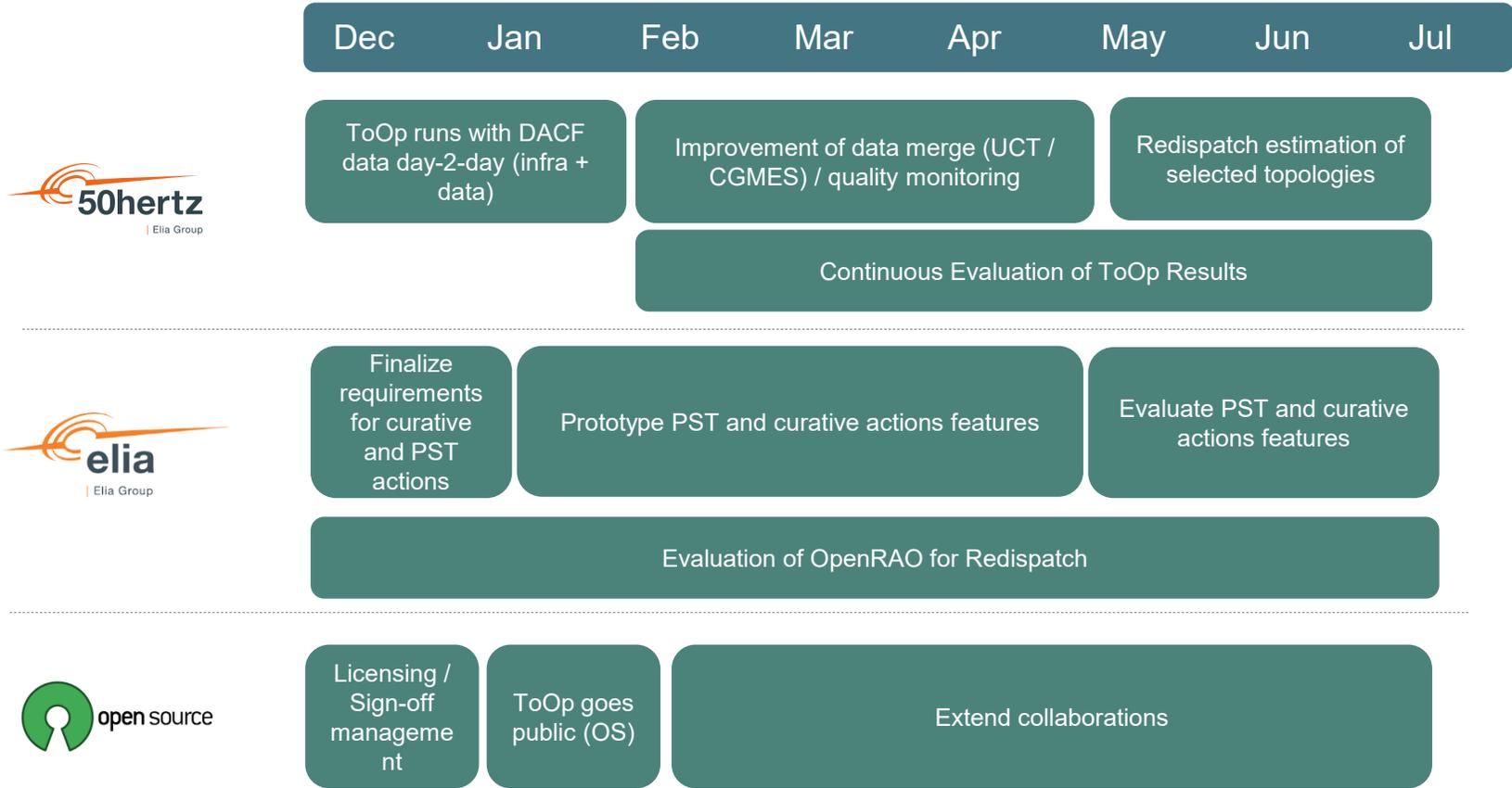


Topology Optimization Newsletter

Danke!

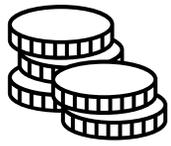


Roadmap - ToOp until Q2 2026

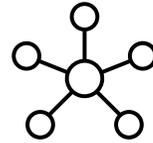


Topology optimization – from Innovation to an open-source product

Challenge & approach



Potential high impact for Elia Group

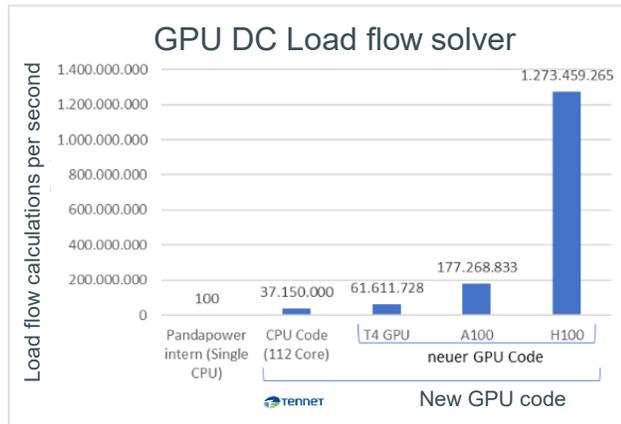


High complex, non linear problem



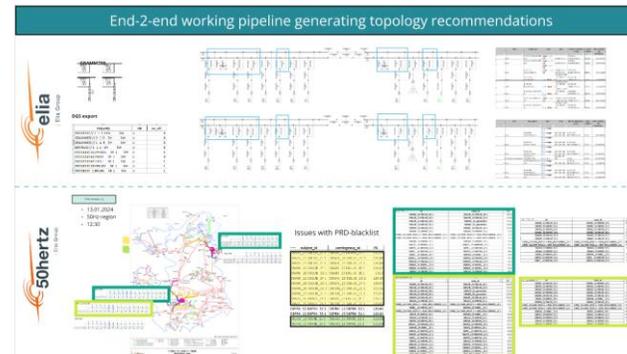
Speed up load flow calculations and optimization in a gpu-native environment

Results



Reference: synthetic Texas Grid (~500 lines, 2000 bus bars) - similar size to the 50Hertz

From 100 to 1 billion load flows per second



Successful topologies on historical data for Elia and 50Hertz



Group Product in testing phase for operational planners at 50Hertz and Elia.



ToOp going **open-source** to enable better collaboration with RTE and TenneT



1

STRATEGY

Become Digital System Operator
by building software inhouse

2

ORGANIZATION

...with a Product Organization
that delivers control center software +
150 FTE

3

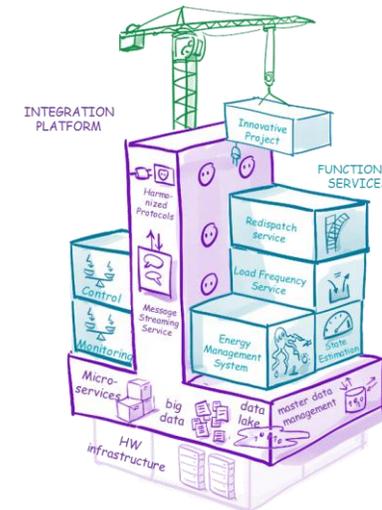
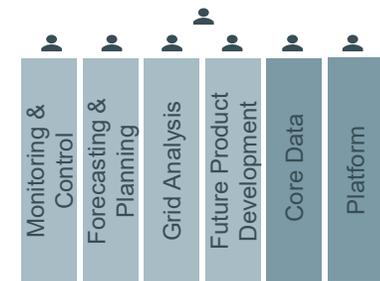
TECHNOLOGY

and Modular Integration Platform
instead of monolithic legacy

4

ECOSYSTEM

to foster Cooperation & Co-creation
so we move away from vendor-lock in



2013

2018

Integrating 100% renewables

2023

2028

2032

38%

56%

72%

85%

100%

