Sharing the operational cost of Europe's electricity grid

Optimization and transparency through open source

Peter MITRI – Réseau de Transport d'Electricité

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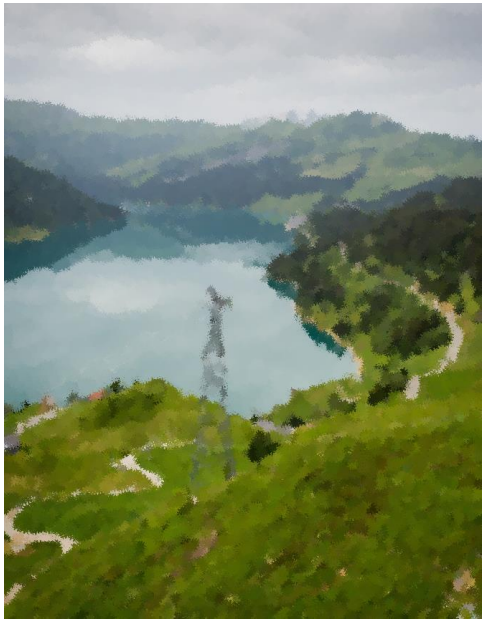
OpenRAO

Flow Decomposition



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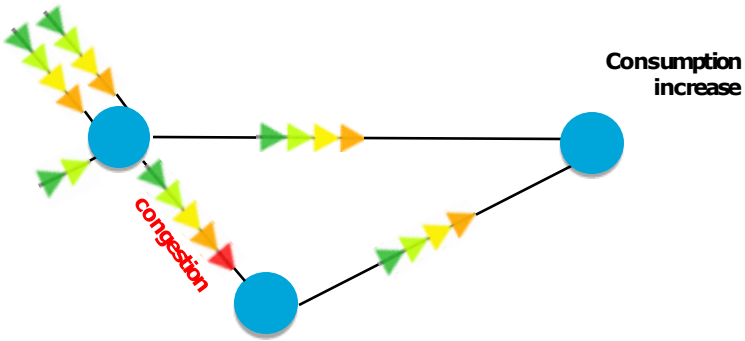
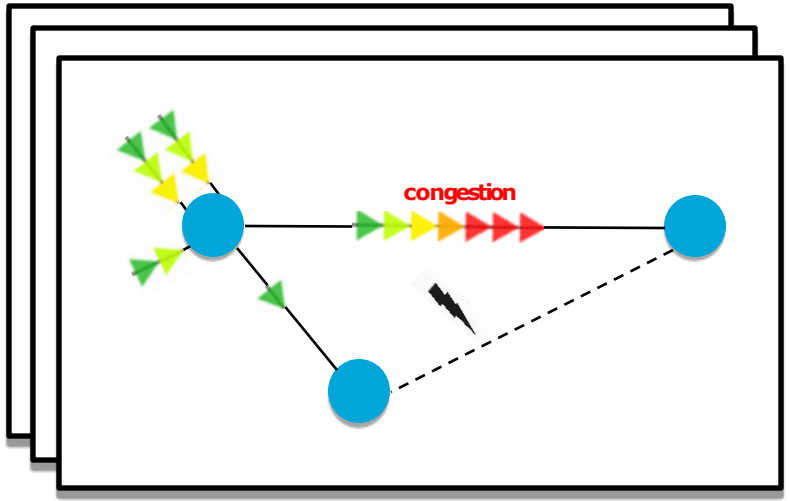
Regional Operational Security Coordination & Remedial Action Optimisation

What is a congestion?





Remedial actions

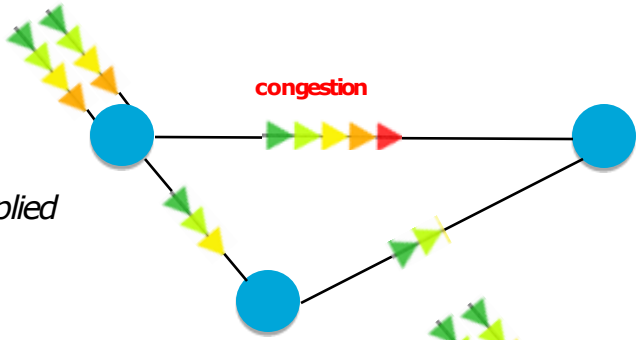
Remedial actions serve two purposes:

- Redirect the flows on the network: topological remedial actions, HVDC lines, or phase-shift transformers.
- Modify the injections on the network: re-dispatching or counter-trading (RDCT), that act on power production.

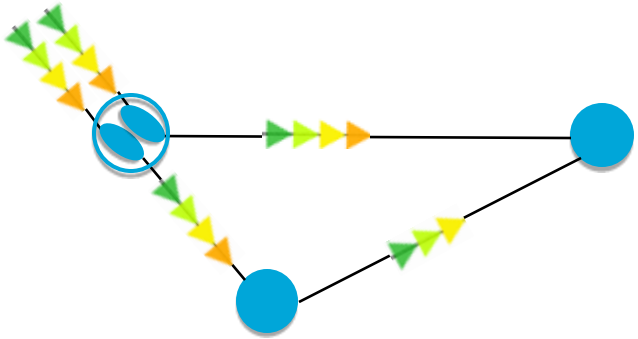
Remedial actions can be either costly or non-costly.

Remedial Actions

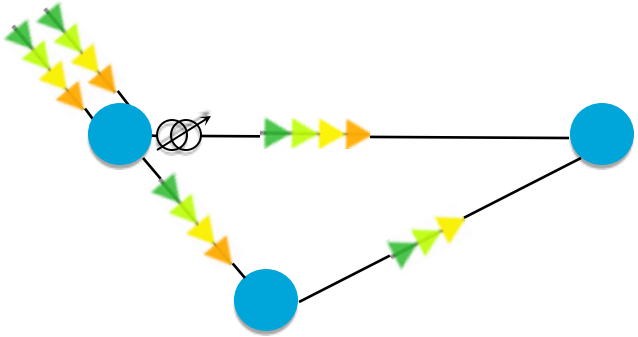
Examples: non-costly remedial actions



No remedial action applied



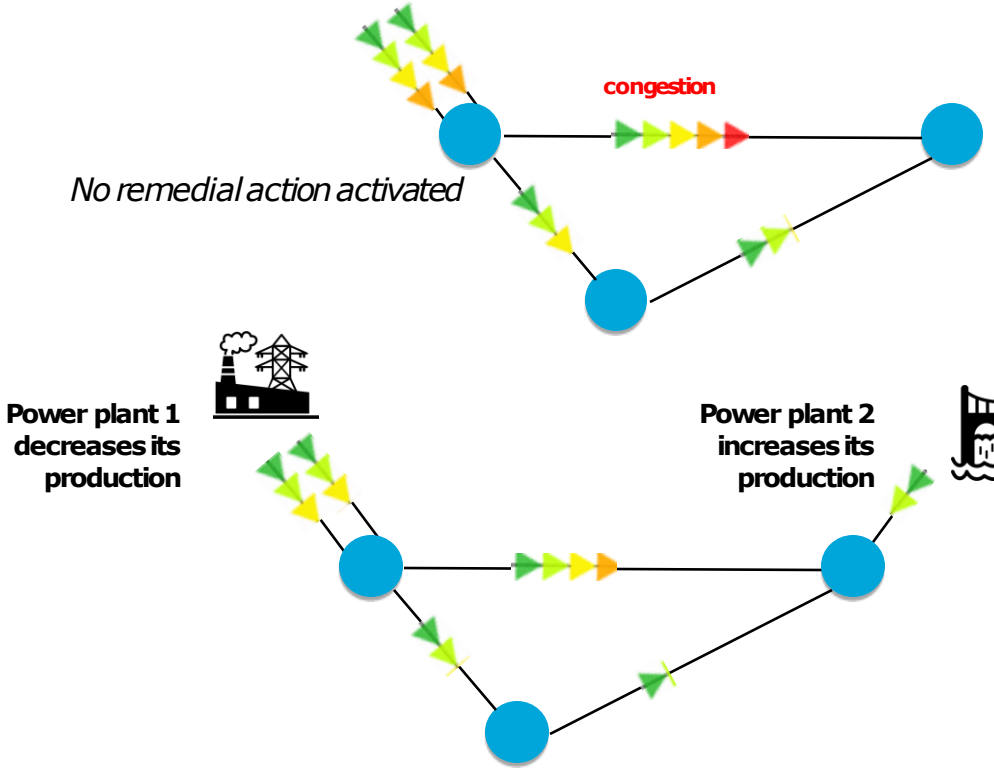
Topological action: 2 nodes in one station



Changing a PST's tap position to move the active power flow

Remedial Actions

Example: costly remedial actions



Remedial Actions

- Europe's TSOs must coordinate to ensure network security at a minimal cost
- Minimizing costs can be achieved using a **RAO (Remedial Action Optimizer)**
- Let's use an open-source RAO!

Source ENTSOE-E: https://www.entsoe.eu/data/map/downloads/

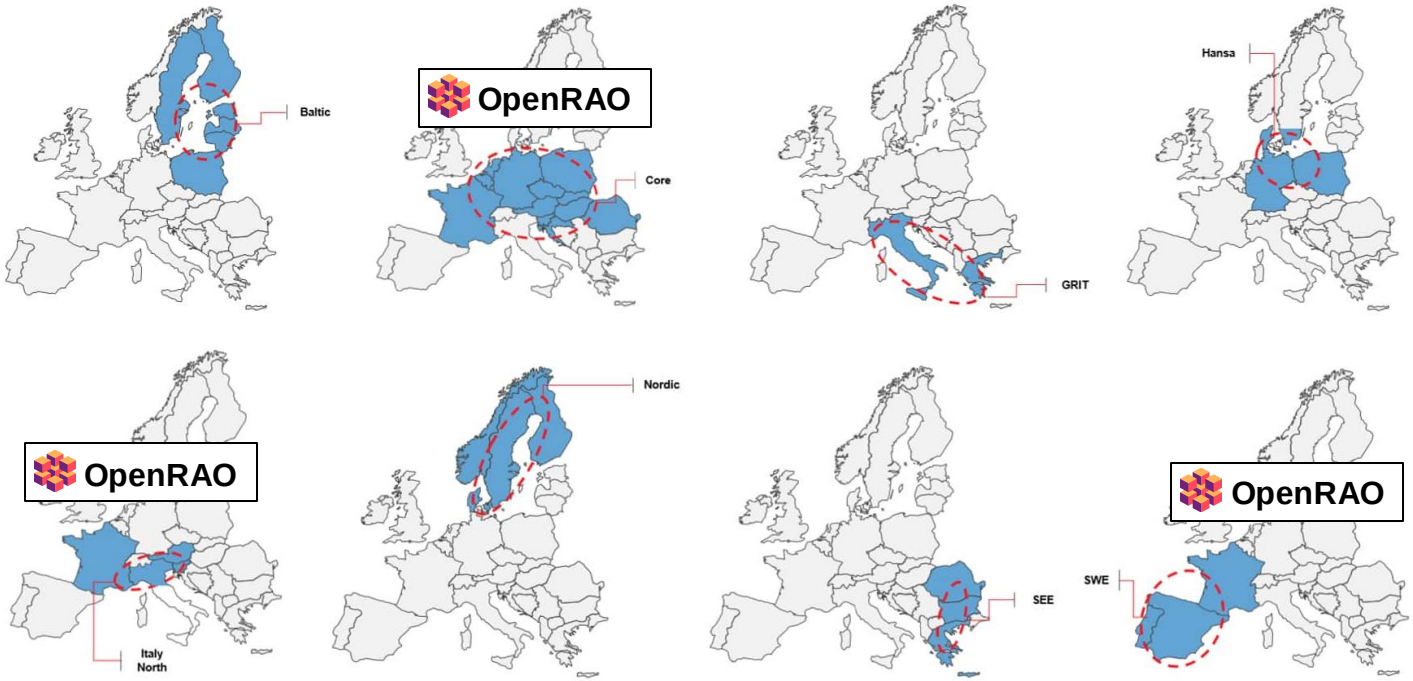
Open Remedial Action Optimizer

farao → PowSyBl OpenRAO

- Open source and transparent
- Currently used in production in many European processes

Code: https://github.com/powsybl/powsybl-open-rao
Documentation: http://farao-community.github.io/

OpenRAO in EU Capacity Calculation Regions



Open Remedial Action Optimizer
Features

Physical constraint	Object model	Optimized by RAO	Monitored after RAO
Flow	✓	✓	
Voltage magnitude	✓		✓
Voltage angle	✓		✓

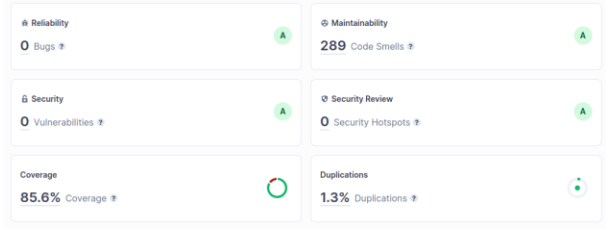
Objective function: minimize the worst congestion, or remove all congestions.
Along with a few other features to tune the RAO, group RAs together, add extra constraints, etc.

Remedial action	Object model	Optimized by RAO
Phase shift transformers	✓	✓ (range or specific set-point)
HVDC setpoint	✓	✓ (range)
Topological action (open/close …)	✓	✓ (binary)
Redispatching	✓	✓ (specific set-point, or range with strong limitations)
Shunt compensator	✓	✓ (set-point only)
Counter-trading	✓	

Open Remedial Action Optimizer

Technical overview

MPL 2.0



SCIP, XPRESS, GUROBI…

Soon! (Q4 2024)

compatible with

Open Remedial Action Optimizer

In practice

Let's build a better RAO together!

Join PowSyBl Slack: https://www.powsybl.org/pages/community/
Then join our channel: https://powsybl.slack.com/channels/rao

Join RAO roadmap discussions in PowSyBl TSC: https://lists.lfenergy.org/g/powsybl-tsc

Quick tutorial (Java): https://farao-community.github.io/docs/tutorials

Contribute to the source code: https://github.com/powsybl/powsybl-open-rao

Read the documentation: http://farao-community.github.io/

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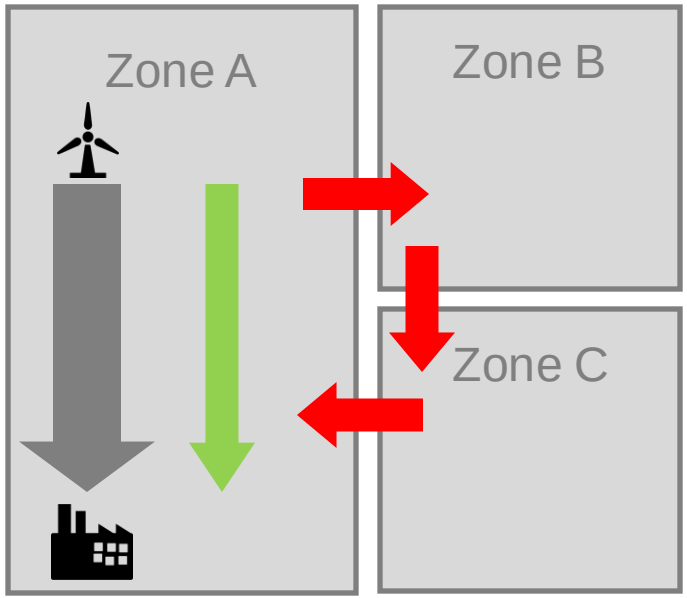
Flow Decomposition & Cost Sharing

Polluting flows (loop flows)



Commercial exchange = Internal flow + Loop flow

ACER methodology

Flow decomposition & cost sharing for CORE region

- Loop flows ► more loads ► more remedial actions ► more costs
- CORE region: up to 3.7B€ per year of RDCT costs
- Computing loop flows can help better share costs
- Let's use an open-source **flow decomposition** tool!

Detailed ACER methodology for flow decomposition: https://www.acer.europa.eu/electricity/market-rules/capacity-allocation-and-congestion-management/redispatching-and-countertrading/19-RDCT-Cost-Sharing-Approved

Open flow decomposition tool

PowSyBl Flow Decomposition

- Open source and transparent
- Follows the ACER methodology
- Java and Python APIs

Example (Python): https://pypowsybl.readthedocs.io/en/stable/user_guide/flowdecomposition.html
Source code: https://github.com/powsybl/powsybl-entsoe/tree/main/flow-decomposition
Documentation: https://www.powsybl.org/pages/documentation/simulation/flowdecomposition

Open flow decomposition tool

Technical overview

MPL 2.0

compatible with

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Questions?

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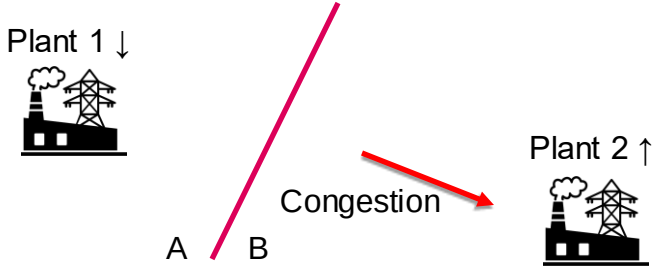
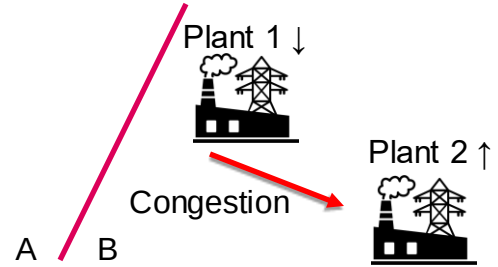
Appendix

Example: costly remedial actions

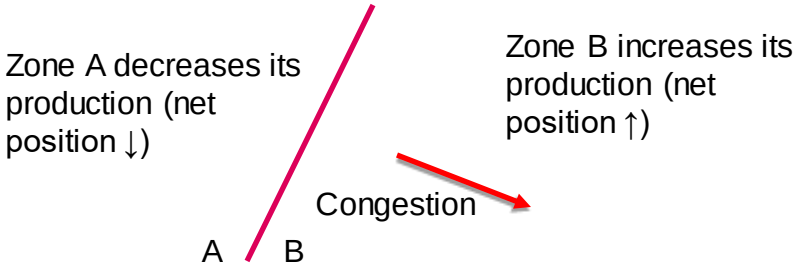
Cross-border re-dispatching



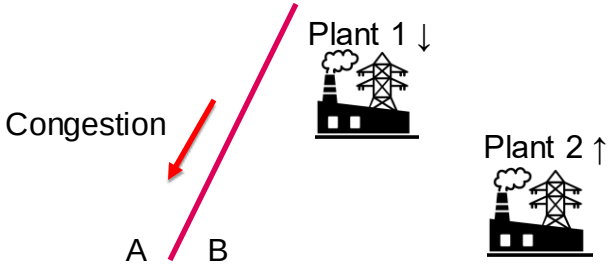
National re-dispatching - Internal



Counter-trading



National re-dispatching - External



Every action should be balanced to zero (to maintain supply-demand balance)

Regional Operational Security Coordination

Coordination of redispatching and countertrading

What is it about?

The methodology describes how TSOs and regional coordination centres of capacity calculation regions manage network congestions at the day-ahead and intraday level. This is done with regionally coordinated application of costly remedial actions, in the so-called ROSC (Regional Operational Security Coordination) process.

This coordination process involves the remedial actions optimisation and coordination in a single day-ahead and multiple intraday operational security assessment rounds (CROSA).

The methodology is closely related with the Regional Operation Security Coordination (ROSC) methodology (Article 76 of the **Guideline on Electricity Transmission System Operation**).

Legal basis: Article 35 of the CACM Regulation

Responsibility: all Transmission System Operators (TSOs) in each capacity calculation region

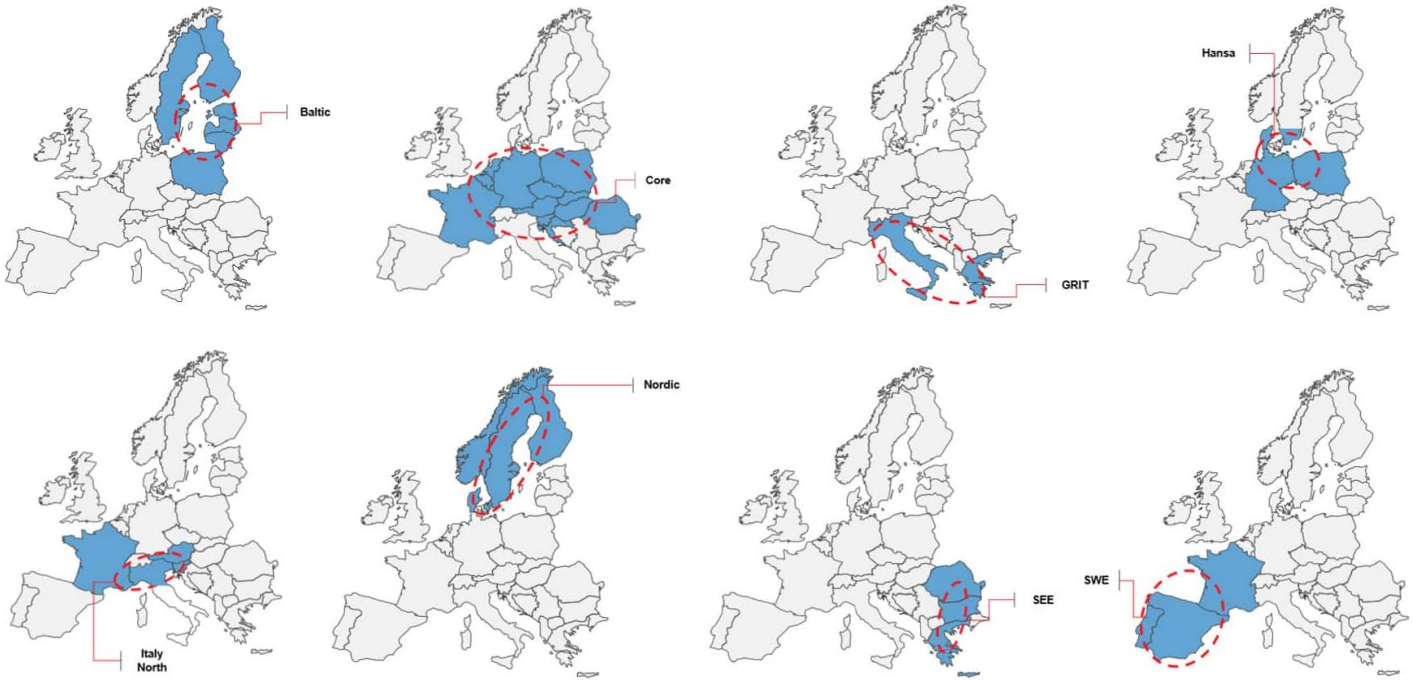
Current status: The methodology was approved in all capacity calculation regions.

Implementation: The methodology is currently being implemented in most of the regions and expected to be fully implemented by the end of 2024.

Source: https://www.acer.europa.eu/electricity/market-rules/capacity-allocation-and-congestion-management/redispatching-and-countertrading

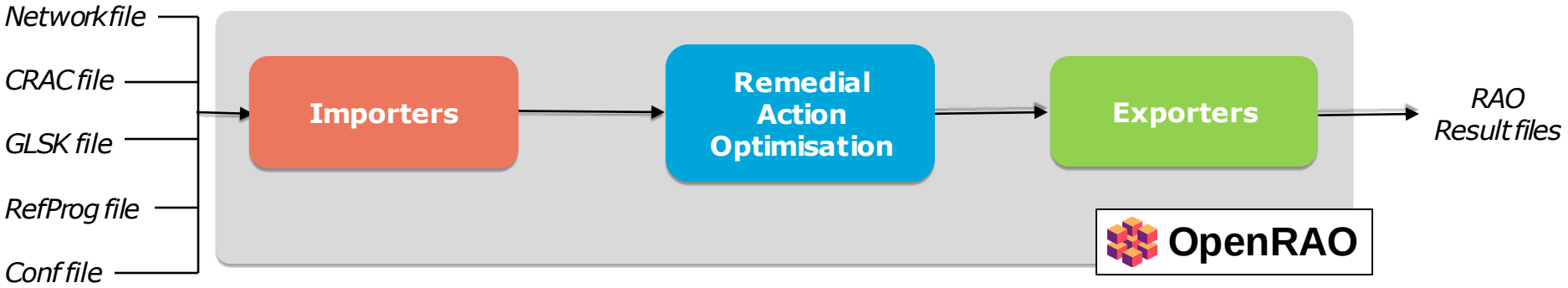
Regional Operational Security Coordination

Capacity Calculation Regions



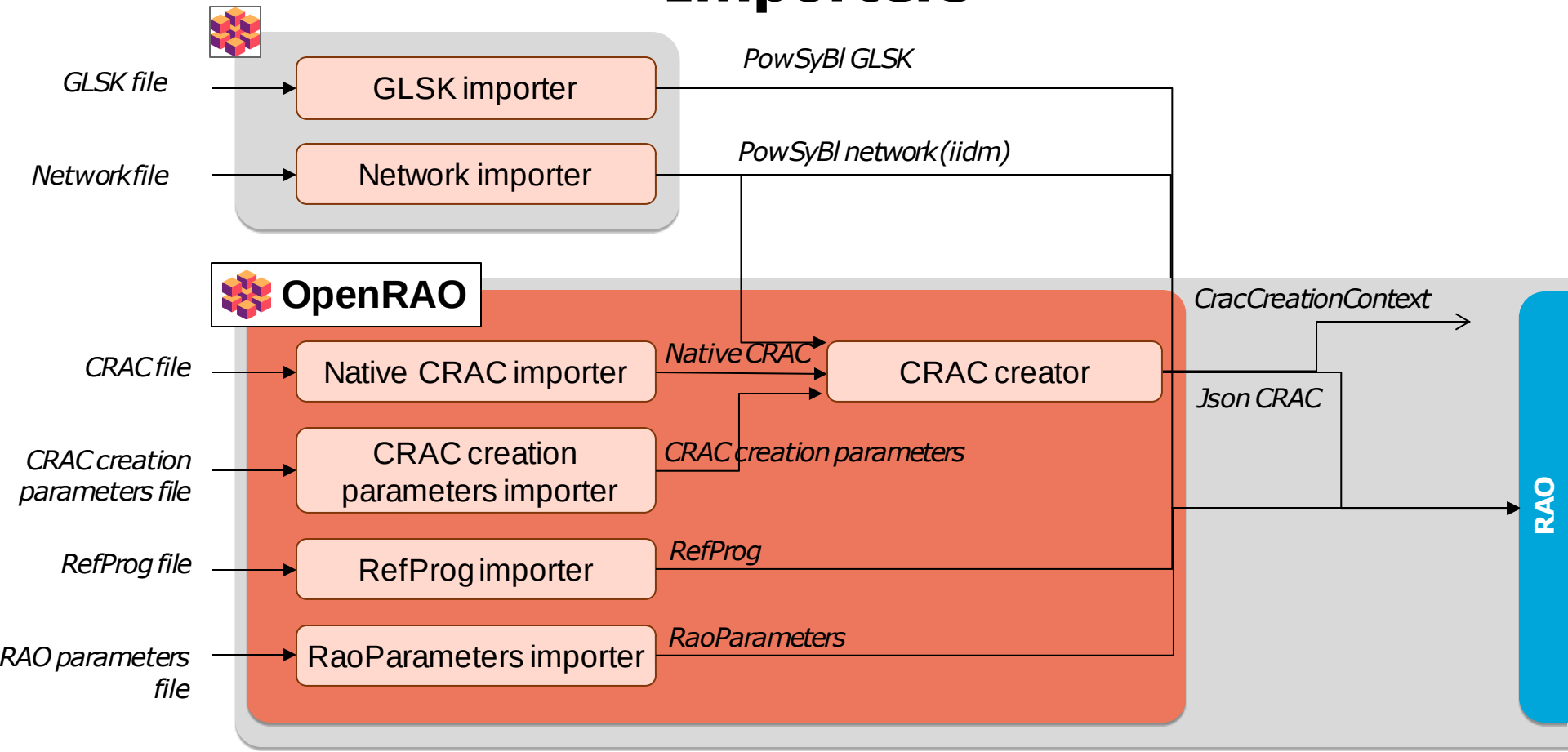
Source: https://annualreport2017.entsoe.eu/network-codes/ (2 removed CCRs)

FOSS Remdial Action Optimizer



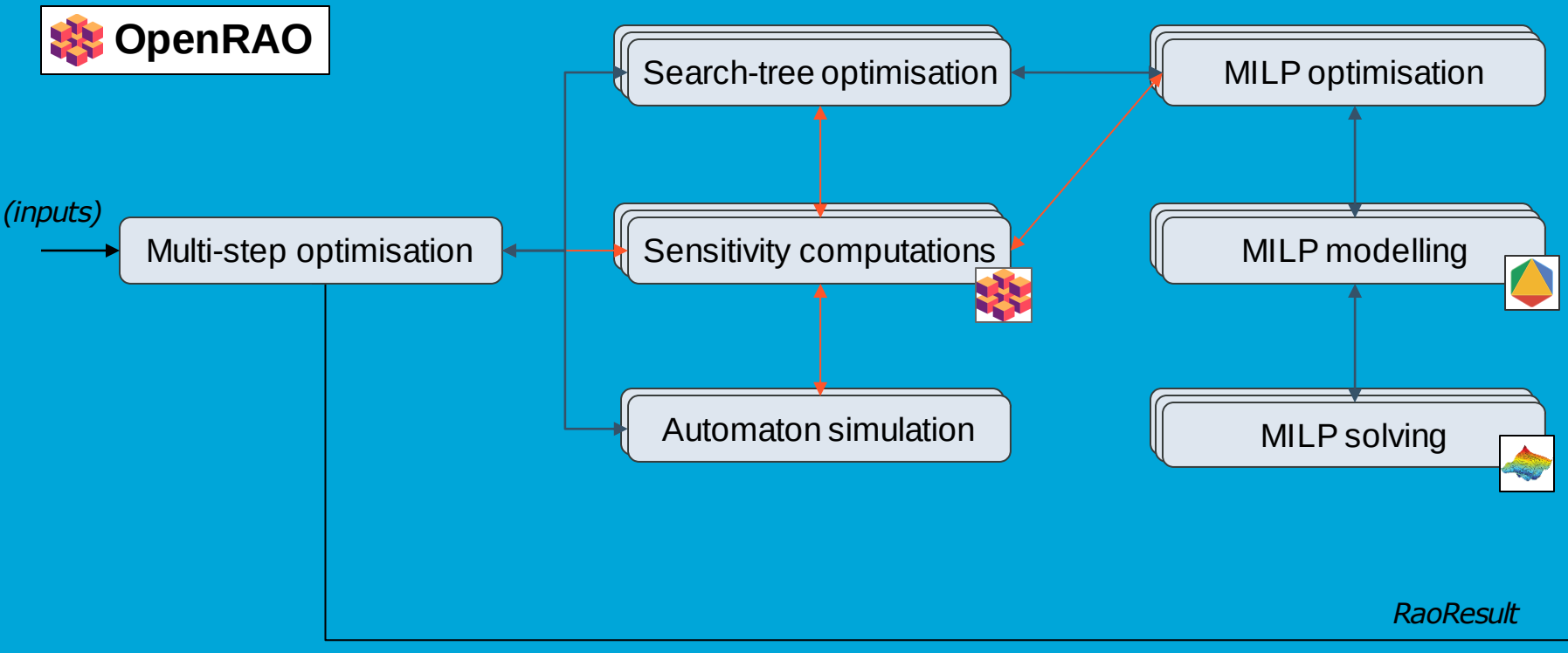
- Network file: file that describes the state of the studied area's network at a given instant (physical elements with their characteristics, and injection values on every node)
- CRAC: Contingency list, Remedial Actions and additional Constraints (list of contingencies, CNECs, and RAs with their characteristics)
- GLSK file: Generator and Loads Shift Key (used to apply a variation of net position on a geographical zone)
- RefProg file: Reference Program (net position of every geographical zone)
- Conf file: configuration of RAO behaviour (OpenRAO-specific)
- RAO Result file: optimal RAs selected by the RAO, flows on CNECs before and after their application, …

Importers


GLSK file
GLSK importer
PowSyBl GLSK
Network file
Network importer
PowSyBl network (iidm)
OpenRAO
CRAC file
Native CRAC importer
Native CRAC
CRAC creator
CracCreationContext
Json CRAC
CRAC creation parameters file
CRAC creation parameters importer
CRAC creation parameters
RefProg file
RefProg importer
RefProg
RAO parameters file
RaoParameters importer
RaoParameters
RAO

Rte

Algorithm



Open Remedial Action Optimizer

Example: optimizing phase-shift transformers

Objective function: $\min(-MM)$

Such that: $MM \leq f^{+}_{threshold}(c) - F(c), \forall c \in \mathcal{C}^{o}$

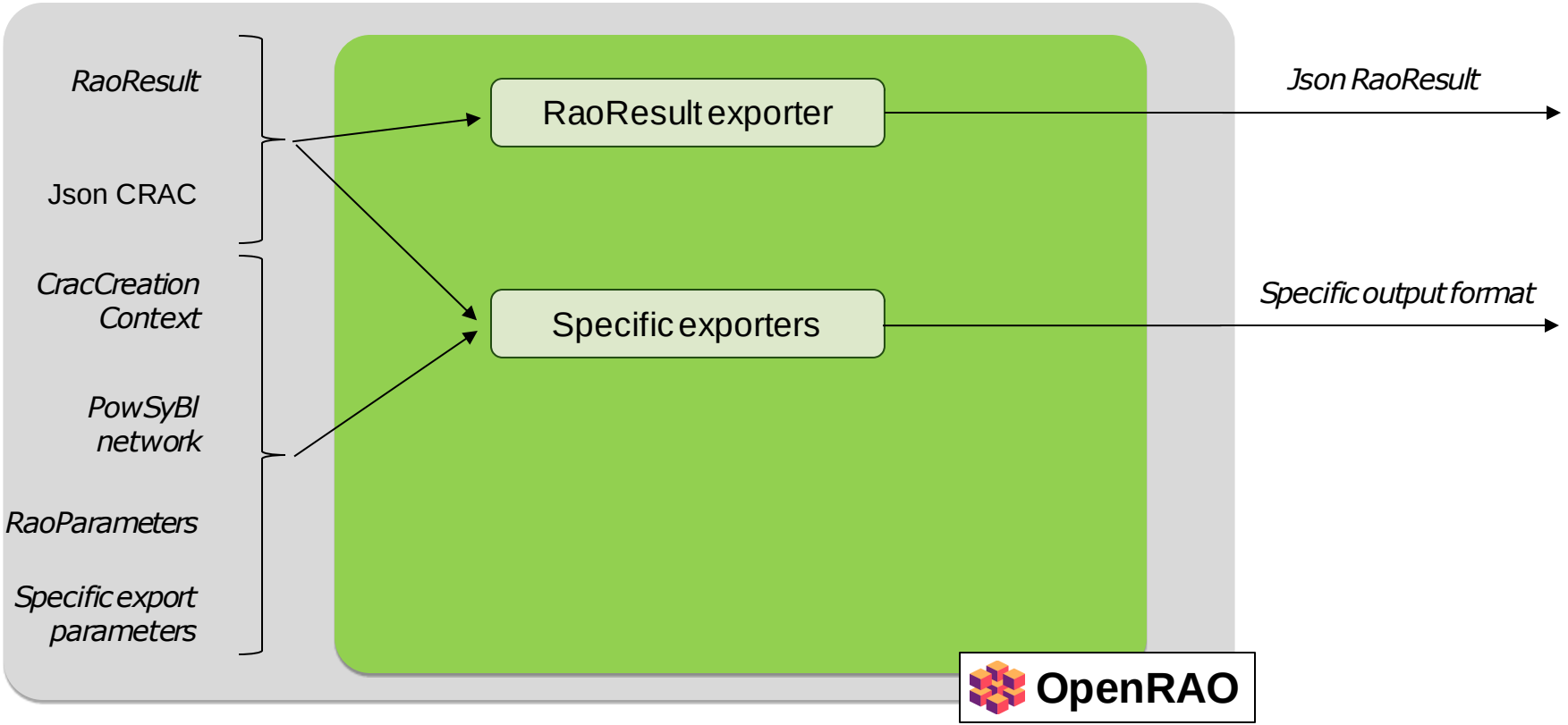
- MM: minimum margin (variable)
- $f^{+}_{threshold}(c)$: maximum admissible flow on line **c** (parameter)
- $F(c)$: flow on line **c** (variable)

And: $F(c) = f_n(c) + \sum_{r \in \mathcal{RA}(s)} \sigma_n(r, c, s) * [A(r, s) - \alpha_n(r, s)], \forall (c) \in \mathcal{C}$

- $f_n(c)$: flow on line **c** before RAO (loadflow output)
- $\sigma_n(r, c, s)$: sensitivity coefficient of PST **r** on line **c** (sensitivity analysis output)
- $A(r, s)$: PST **r** set-point (variable)
- $\alpha_n(r, s)$: PST **r** set-point before RAO (parameter)

Source: https://farao-community.github.io/docs/engine/ra-optimisation/search-tree-rao

Exporters


RaoResult
Json CRAC
CracCreation Context
PowSyBl network
RaoParameters
Specific export parameters
RaoResult exporter
Specific exporters
Json RaoResult
Specific output format
OpenRAO

Cost sharing

Cost sharing for coordinated redispatching and countertrading

What is it about?

The methodology establishes the rules TSOs need to follow to determine the different categories of flows (loop, internal, phase shifting transformers, allocated flows) which created network congestions for each capacity calculation region and how the respective costs are shared among TSOs.

The process

- Once resolved in the Regional Operation Security Coordination (ROSC) process by engaging the remedial actions, the polluting flows are mapped accordingly.
- The costs of engaging the costly remedial actions are appointed to the specific TSOs which create the polluting flows.

Legal basis: Article 74 of the CACM Regulation

Responsibility: all TSOs in each capacity calculation region

Current status: The methodology was approved in all capacity calculation regions except of Italy North.

Implementation: The methodology is currently being implemented in most of the regions along with the redispatching and countertrading methodology. The implementation in all regions is expected by the end of 2024.

Source: https://www.acer.europa.eu/electricity/market-rules/capacity-allocation-and-congestion-management/redispatching-and-countertrading

ACER methodology

Flow decomposition for CORE region

Nodal injection decomposition is done as follows:

$$\begin{aligned} NI_{AF} &= GLSK \cdot NP \\ NI_{LIF} &= NI - NI_{AF} - NI_X \end{aligned}$$

where:

- NI is the vector of the network injections,
- NI_X is the vector of the network injections from dangling lines,
- NI_{AF} is the vector of allocated flow part of the network injections,
- NI_{LIF} is the vector of loop flow and internal flow part of the network injections,
- NP is the vector of the zones' net position,
- $GLSK$ is the matrix of the GLSK factors for each injection in each zone,

Based on previously calculated elements, flow partitioning can now be calculated as follows:

$$\begin{aligned} F_{AF} &= PTDF \cdot NI_{AF} \\ F_{LIF} &= PTDF \cdot \mathrm{diag}(NI_{LIF}) \cdot AM \\ F_{PST} &= PSDF \cdot \Delta_{PST} \\ F_X &= PTDF \cdot NI_X \end{aligned}$$

where:

- F_{AF} is the vector of the network element allocated flow,
- F_{LIF} is the matrix of the network element loop flow or internal flow for each zone,
- F_{PST} is the vector of the network element PST (phase shift transformer) flow,
- F_X is the vector of the network element xnode flow,
- AM is the allocation matrix, which associates each injection to its zone. AM_{ij} = 1 if node i is in zone j, 0 otherwise,
- Δ_{PST} is the phase shift transformers angle vector,

Source : https://github.com/powsybl/powsybl-entsoe/tree/main/flow-decomposition
Detailed methodology : https://www.acer.europa.eu/electricity/market-rules/capacity-allocation-and-congestion-management/redispatching-and-countertrading/19-RDCT-Cost-Sharing-Approved