Geographical approach of congestions on the sub-transmission grid in France

CONTEXT

In a context of energy transition, the growth of Renewable Sources of Energy (RES) connected downstream the main transmission grid creates additional congestions on those voltage levels. Notably, the voltage range between 60 and 150 kV is the stage of new congestions in European countries like Germany, Italy, and France. With the objective of explicitly or implicitely modeling chosen parts of the sub-transmission grid among the French main transmission grid model, this study provides a methodology to identify the factors the most correlated to congestions. It relies on geographical open data, using the QGIS python interface to automate processing and deduce trends for further grid studies.

DATA & INDICATORS

Open data processed in this study covers geographical (production and consumption per type and IRIS mesh, population density) and grid-related (lines, cables, substations, data from Capareseau) fields.

In addition, congestion data from the RTE ODRE database must be treated to map zones _whose definition rules are not given. This dataset gives, per RTE zone :

- the sum of non-transmitted power due to congestions
- the number of congestion occurrences (on branches and substations)
- the non-transmitted cumulated energy volume over the year 2022 (see Fig. 1). Regions studied show almost exclusively congestions on sub-transmission lines.

The scale of study must be of the same order of magnitude as the scale of impact of the sub-transmission grid. Other open data from RTE are processed (see Fig. 2), giving a scale of impact that is in the same order of magnitude than RTE zones.

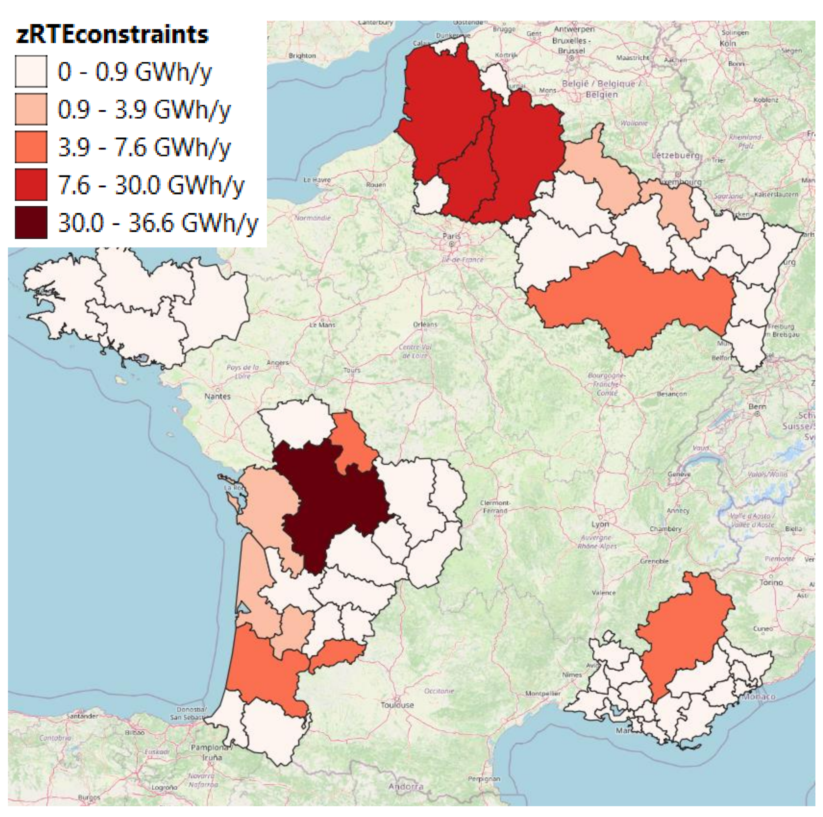

Figure 1: Constraints data for chosen RTE zones with the non-transmitted energy volume

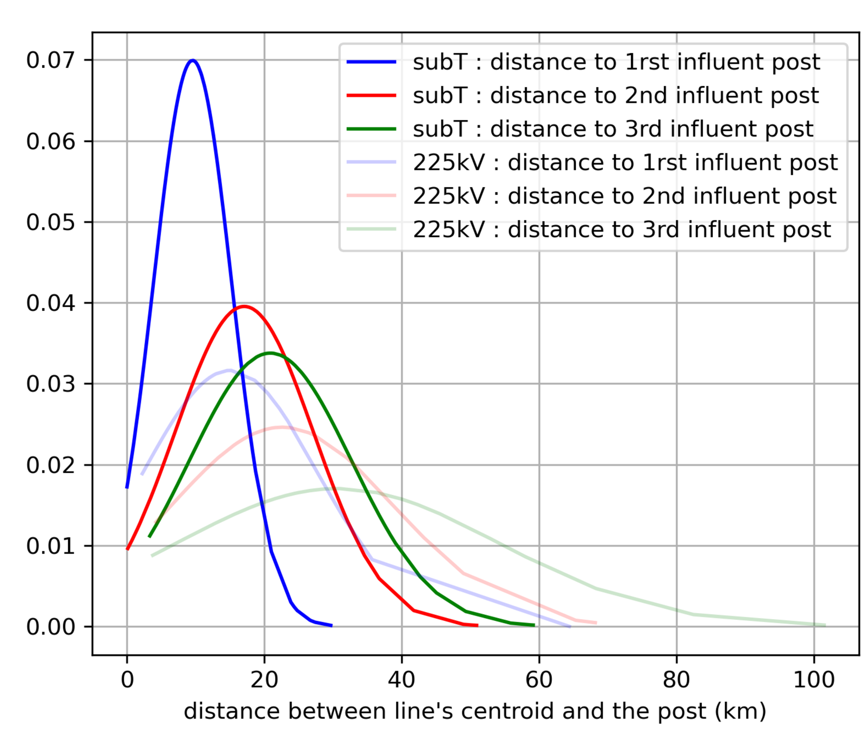

Figure 2: Normal distribution of distances from sub-transmission lines' and 225 kV lines' centroids, to their 1rst, 2nd, and 3rd most influent posts, respectively

Hypotheses on factors correlated to congestions are put forward: proximity to RES (H2), distance between RES and consumption poles (H3), low meshing density (H4) and limited S3REnR connection availability on substations (H5).

Indicators are then calculated per RTE zone (see Table I).

Data type	Indicator fields	Objective of study and concerned hypothesis	Nb of indicators
Geographical	Total installed capacity and annual energy produced, by type of power plant	Spot RES production (H2) and compare it to consumption (H3)	20
	Annual consumption per sector	idem (H3)	5
	Statistics on the population and its spatial distribution	study the link between low housing density and congestion (H3, H4)	6
	Area of zones	standardise data	1
Grid	Nb of substations per voltage level	observe the link with grid density (H4)	5
	Length and number of lines and cables per voltage level	idem (H4)	20
	Capareseau data on available capacity for S3REnR connection, total substation capacity, transformer power, etc.	observe the remaining availability of substations (H5)	7
	Nb of border crossings by lines and cables, per voltage level	observe the interconnection with neighbouring zones (H4)	10
	Grid meshing density by voltage level	idem (H4)	5

Table I : Indicators studied

METHODOLOGY

Three autocorrelation studies are processed based on the calculated indicators.

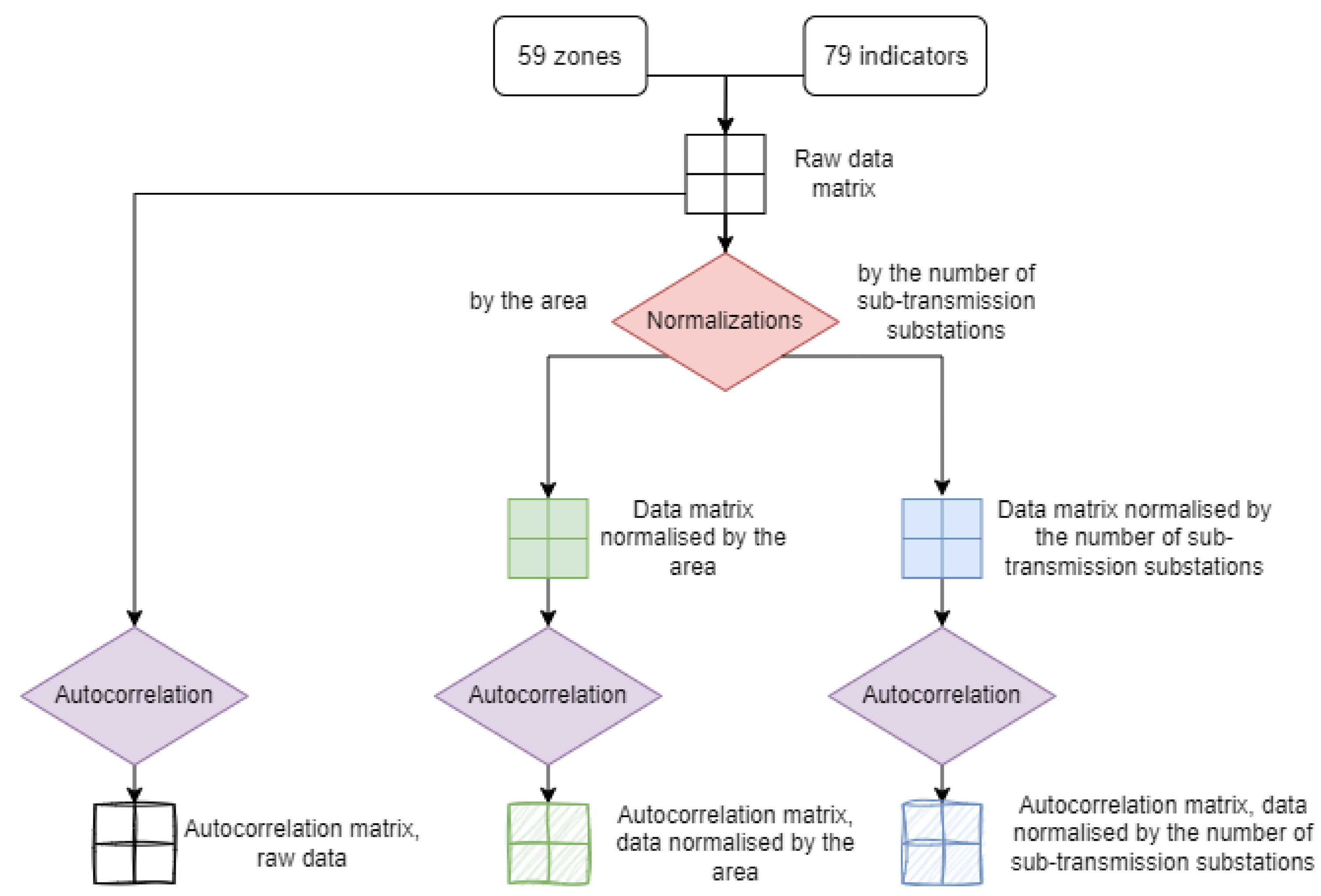

Figure 3: methodology

RESULTS & VALIDATION

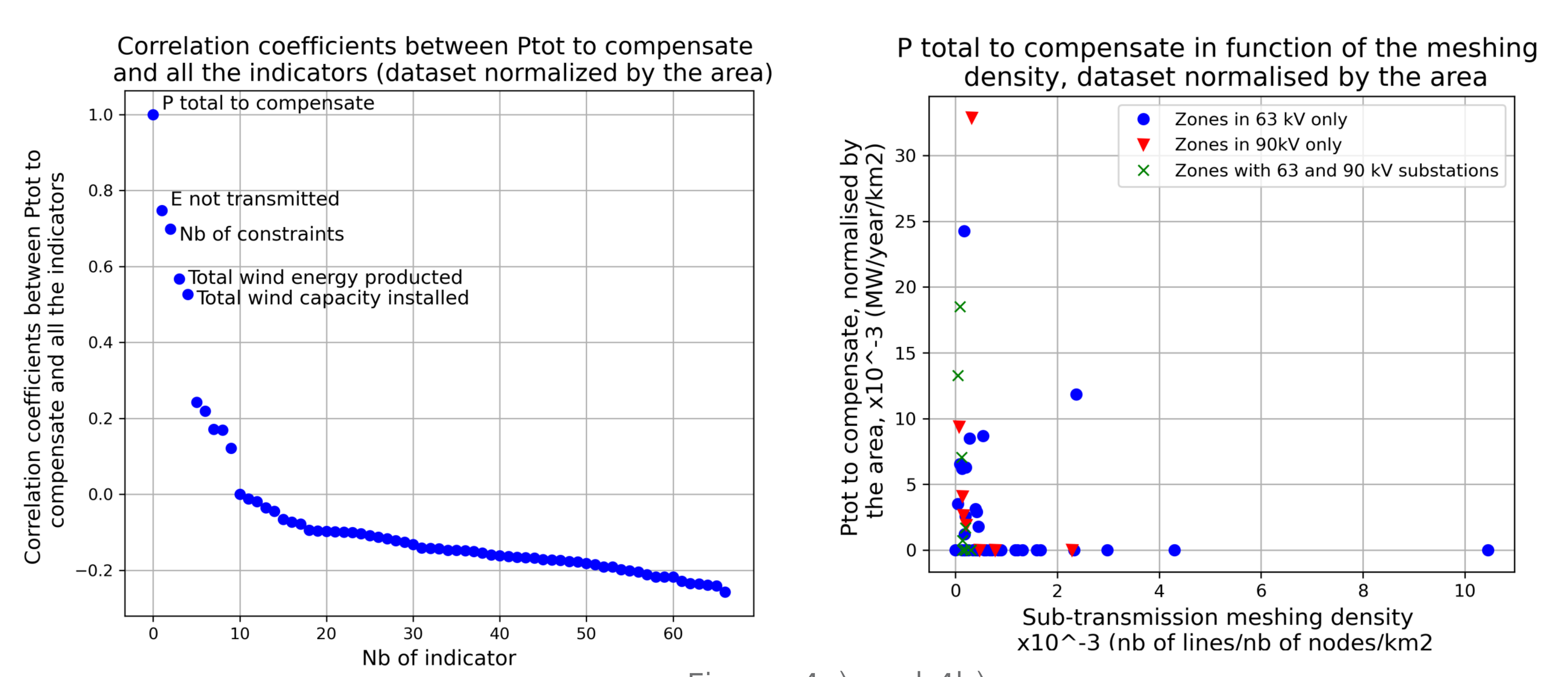

Figure 4a) and 4b)

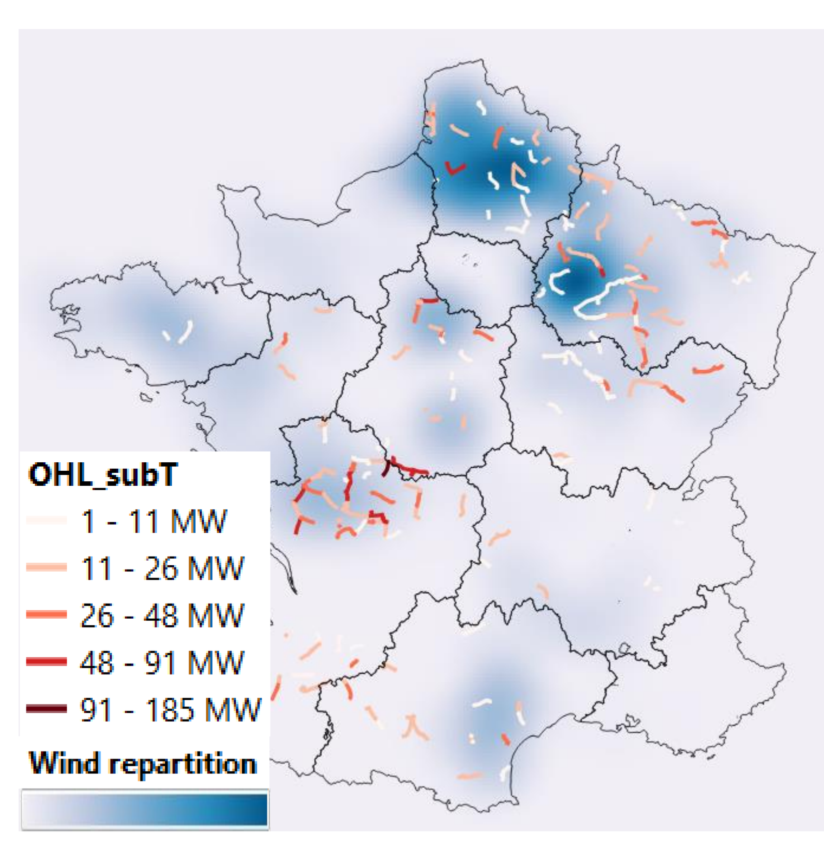

Figure 5: Heat map of the number of wind turbines installed, vs the prospective residual constraints and thus flexibility needs to address sub-transmission lines overloading (at least once)

- Wind installed capacity and annual energy production are the indicators the most correlated to congestions, whether it is normalized by the area or by the number of sub-transmission substations. Even though the correlation remains weak, it corresponds to observation on another dataset with prospective residual constraints, and thus flexibility needs to address sub-transmission lines overloading versus the heat map of wind turbine number (see Fig 5).
- A threshold effect is observed on the meshing density (after a meshing density of 8.10^{-4} nb of lines/nb of nodes/km², nearly no congestions are observed).

CONCLUSION & PERSPECTIVES

- Correlation with wind installation, threshold effect on the meshing density
- Other hypotheses were made (notably on correlation with low housing density or availability on substations for S3REnR connection), which are not validated
- Further work should be continued on the implicit or explicit modeling of areas at risk of sub-transmission congestions

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