

NFDI4Energy Conference

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Grid Matching Tool

Abstract for the 1. NFDI4Energy Conference 2024

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Abstract: In this paper, a tool to compare grid models at the highest resolution possible is presented. It takes as input two georeferenced grid models and outputs an identification between clusters of nodes in each model. The tool can be used to transfer data between models, compare them and also create a new model with the highest resolution from the input models.

Keywords: Energy System Modelling, Energy System Comparison, FAIR data, Energy research software

1 Introduction

Energy systems are usually modeled as complex grids. These are graphs with attached data related to demand, generation or transport of energy. They could even combine different grid levels for electricity, heat, gas and transport. Open-source models of the same energy system can differ greatly due to modelling simplifications or the lack of accurate open-source data. In order to enrich and validate these models, tools to compare them and transfer data between them are necessary. This is usually done using rough global parameters, but with the increasing share of distributed energy components (like renewable sources or small storage units) a finer tool is needed.

The need for such a tool was seen during the project MODEX-Net [1-3], in which 8 different European grid models focused on Germany were compared at different levels. During the project, it was possible to compare the models in many different ways: Set of technical parameters, market optimized models at national level, installed capacities and load at NUTS 3 level, and plots of the line overloads. The present tool can be used to make grid models comparable at a higher space resolution by identifying clusters of nodes between different models of the same or nearby grids. In Section 2, the methodology behind the tool will be presented and in Section 3 some applications using concrete use-cases will be discussed. Finally, in Section 4, some conclusions will be drawn about the current and future applications of the tool.

2 Methodology

In this section, the main ingredient behind the tool is sketched, which is an identification between clusters of nodes of two grids.

Given two georeferenced grid models A and B , we assign to each node a in A the closest node $f(a)$ in B using the Euclidean distance and to each node b in B the closest node $g(b)$ in A . Now we define a node a to be a *center* of a cluster in A if $g(f(a)) = a$ and a node b to be the center of a cluster in B if $f(g(b)) = b$. This way, we have a one-to-one identification between centers. The rest of nodes in A (respectively in B) are assigned to a center using the shortest path. Hence, we obtained a clustering in A , a clustering in B , and a one-to-one correspondence between their clusters.

3 Use cases

In this section, some applications of the tool are presented. In the data repository accompanying the tool, there are already five open-source grid models [4-8]. In this paper, the eTraGo grid with version 0.4.6 with the Status Quo scenario [5] and the PyPSA-Eur grid model version *elec_s_1024.nc* [7] are used.

Identification of clusters of nodes between two network models

In Figure 1, the clusters of the identification between eTraGo and PyPSA-Eur restricted to Germany are plotted. The lines plotted in orange are the ones contained inside a cluster (*intra-cluster*), and the convex hulls of the clusters of the eTraGo grid are plotted as shadows.

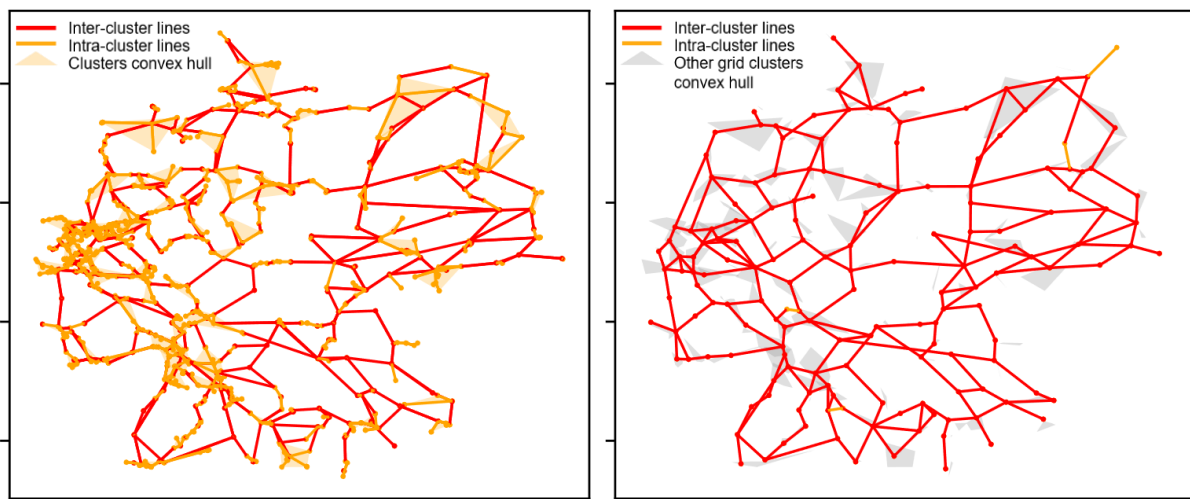


Figure 1. Identified clusters for the eTraGo (left) and PyPSA-Eur (right) German grids.

Notice how, with this visualization, it can be recognized at one glance that the eTraGo model has a higher spatial resolution. This is not surprising, since the eTraGo grid model uses the highly resolved SciGRID model [8] with no spatial simplification and PyPSA-Eur model is a clustered version of SciGRID. However, using the finer identification provided by the present tool these two models can interact, as shown in the next subsections.

Comparison of data in nodes between models

In Figure 2, the wind onshore installed capacities aggregated at cluster center level are plotted side by side.

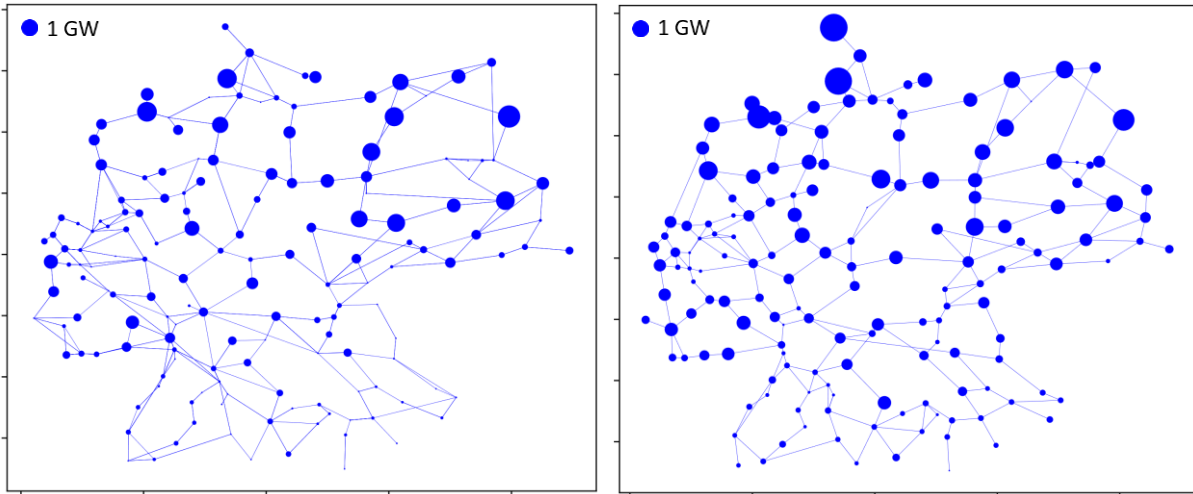


Figure 2. Installed capacities of wind onshore in Germany in eTraGo (left) and PyPSA-Eur (right) aggregated per cluster.

A first observation is that PyPSA-Eur has more wind onshore installed capacity in Germany (54.38 GW in contrast to 29.8 GW), which is expected, since it is a current model whereas the status quo scenario of the eTraGo grid uses data from 2012. But what is more interesting is that with the present tool one can differentiate at a local level how the installed capacity is distributed and even define indicators that take local information into account to compare different models. For instance, one can calculate the RMSE of the wind onshore installed capacities in the cluster centers, which gives 0.33 GW. This number gives an estimate of the local deviation that can be used to compare multiple models.

Comparison of the grid model topology

In Figure 3, the clustering of the two grids are shown. In black are the lines present in both grid models and in red the lines that only appearing in one. Although, altogether they are very similar, the present tool gives the opportunity to get much more detailed local information.

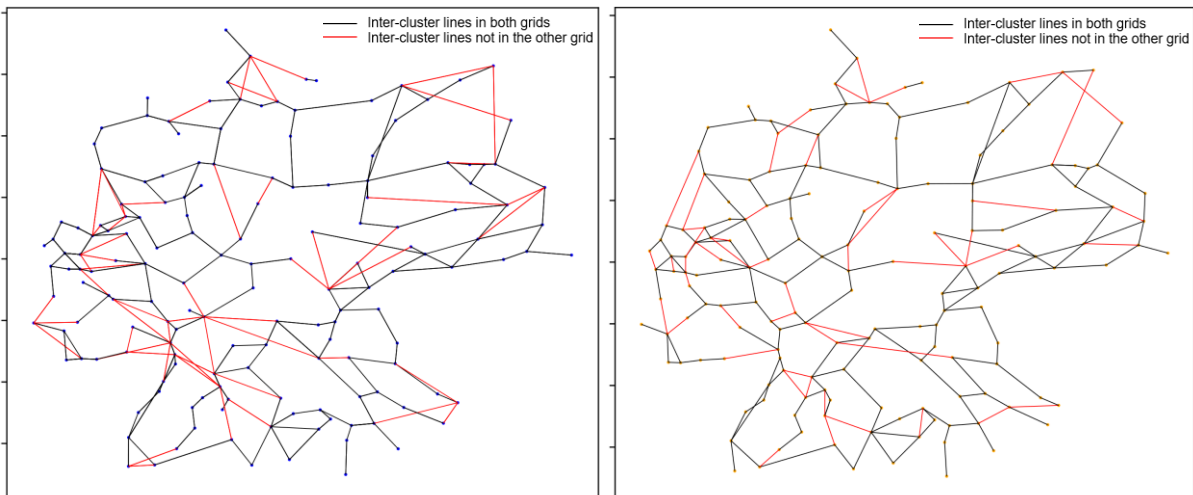


Figure 3. Clustered eTraGo (left) and PyPSA-Eur (right) German grids.

Transfer data from one grid model to another

In Figure 4 (right), the PV installed capacities in the PyPSA-Eur grid model for Germany are plotted aggregated at the cluster centers. This information can be used to transfer this data to

the eTraGo grid model, for instance, by distributing it uniformly inside each cluster (as seen on Figure 4, left). More elaborate distributions can be used if more information is available.

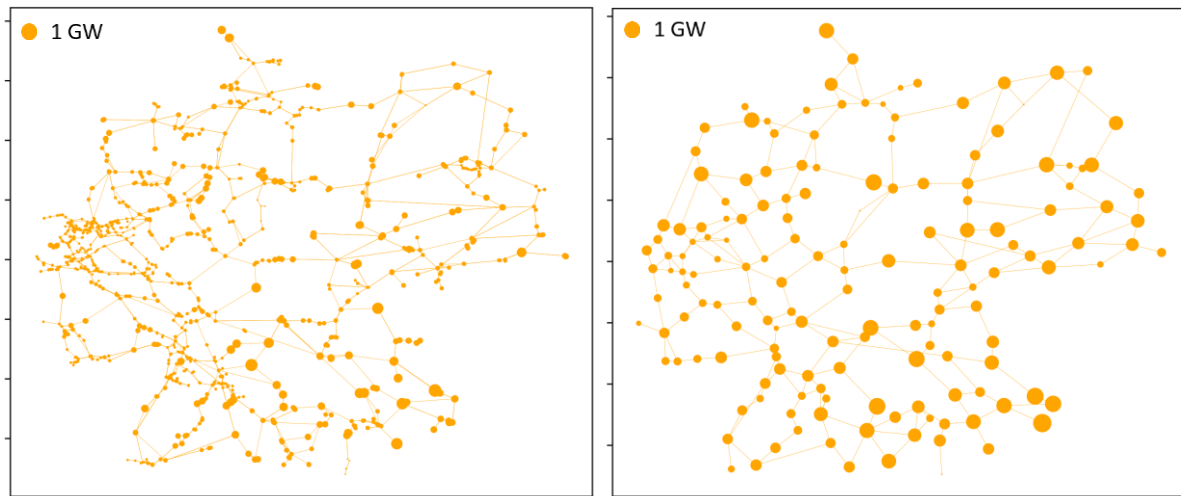


Figure 4. Relative installed capacities of PV in Germany in eTraGo (left) transferred from PyPSA-Eur (right).

Join two grid models

In Figure 5, it is shown how the cluster identification provided by this tool can be used to join two networks using the clusters with the highest resolution from each one.

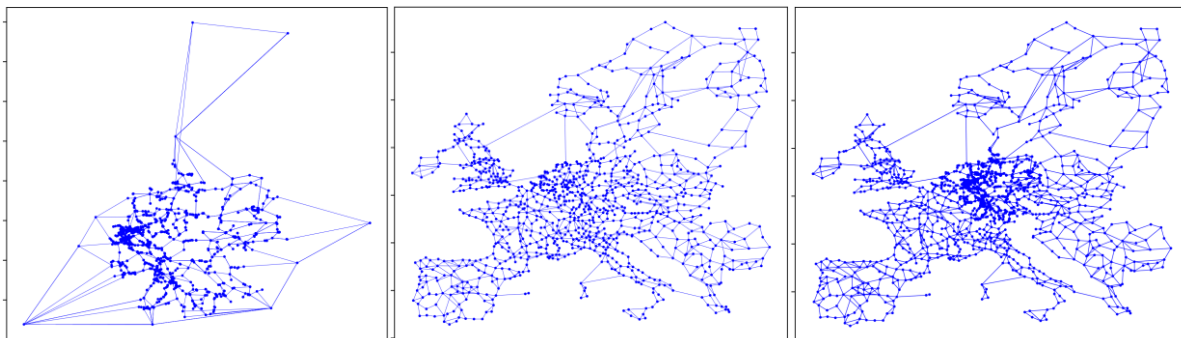


Figure 5. eTraGo grid model (left), PyPSA-Eur grid model (center) and the joined network using the clusters with higher resolution from each (right).

As expected, the joined network uses eTraGo in Germany and PyPSA-Eur everywhere else. This is because eTraGo models the German grid down to 110 kV, but the other countries with only one node per country and PyPSA-Eur models all Europe, but clustering the transmission grid to a convenient size.

4 Conclusions

The tool presented in this paper enables the cooperation of different grid models by matching clusters of nodes between them. The tool has been presented applied to concrete open-source models of the German and the European grids. In particular, the tool can be used to compare data in the nodes (like installed capacities), transfer data from one model to the other, and join two grid models into one using the highest local resolution of each one. The tool has a big potential for applications once it is linked to more open-source models and it can also be used with other types of networks (like gas, heat or water).

Data availability statement

The tool and use-cases will be published on <https://gitlab.com/dlr-ve-esy/> under MIT license.

Author contributions

Oriol Raventós: Conceptualization, Methodology, Software and Writing – Original Draft Preparation.

Abhilash Bandam: Conceptualization, and Writing - Review & Editing.

Theresa Groß: Conceptualization, and Writing - Review & Editing.

Ontje Lünsdorf: Conceptualization, Methodology, Software and Writing – Original Draft Preparation.

Competing interests

The authors declare no competing interests.

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