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Correlation Between Costs of Congestion Management and Share of Renewables in the ENTSOE Continental Europe Synchronous Area

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Abstract.

The presented research is dedicated to estimation of the correlation between the level of renewable energy sources and the costs of congestion management in electric networks in selected European countries. Data of six countries in North-West European area (Italy, Spain, Germany, France, Poland and Austria) were investigated. Factors considered included grid congestion costs including re-dispatching costs as well as countertrading costs, gross electricity generation, installed capacity of electric generating facilities, installed capacity of electric non-dispatchable renewable energy sources and total electricity consumption. Special attention is paid to the share of renewable energy sources. It is found that the grid congestion costs are not clearly affected by penetration of non-dispatchable renewables in all the analysed countries and therefore a clear mathematical correlation cannot no be extrapolated with the available data. The results of this research show in general a loose dependency of the grid congestion costs on the penetration of renewables and a strong dependency on the total electrical consumption of the country.

Key words. Renewables, energy market, load balancing, congestion management, network operation costs.

1. Introduction

This research work builds upon the hypothesis that the increase of the share of non-dispatchable renewable energy sources in electricity production leads to bigger expenditures associated with management of congestions in electric networks at transmission level. The objective of this research is to prove that there is a correlation between these two factors and to use various indices of electric energy systems to contrast their effect in the costs of electric grids management in selected European countries.

Renewable energy sources are nowadays an important supporting pillar of our power systems. Wind and solar generating facilities are dominating among them. Since their production depends on external factors, they are treated as non-dispatchable renewable energy sources (RES). That means, that their generation cannot be adapted to the load demands and often they cannot even be predicted precisely enough. Due to the special characteristics of the production with non-dispatchable RES, in terms of stochastic production, it is necessary to differentiate between energy and capacity. Therefore, the analysis presented in this paper will be performed from two points of view, energy production and available capacity.

This paper will provide an analysis of the problem of grid congestions costs in electrical networks, then present a set of assumptions and parameters to be considered, the results of the analysis based on those assumptions and draw conclusions.

2. Problem of Grid Congestion Costs in Electric Networks

The power system operators strive to operate their networks so that to achieve the most efficiency, provided that their networks are stable and safe. To prevent system damage or shortage of transmission capacity due to grid congestion, the grid operator is required to implement congestion management techniques. Those grid congestion management techniques are expensive and the costs are eventually paid by final energy customers via their grid service charges. Therefore, it is in the best interest of all the involved actors to avoid the risks of bottlenecks in power systems operation. On the other hand, it is a common perception that higher shares of stochastic distributed generation are increasing the grid congestion risks and therefore are partially responsible for the high costs of the grid congestion management.

Many works in this field have approached this issue by providing analysis of the existing congestion management methods for distribution networks with high penetration of renewables, such as [1], [2] or [3]. A more modern view of the problematic is considering the complementarity of multiple energy resources in energy hubs (EHs) to mitigate possible distribution network congestions, combining different types of energy resources [4] or combining it with storage [5]. This paper does not attempt to analyze the problem itself or propose any solution, but to find a correlation between the cost and the phenomenon itself.

The grid congestion costs considered in this paper include re-dispatching costs as well as countertrading costs. Re-dispatching refers to the situation when the day-ahead market clearing solution results in grid congestion. This problem may be resolved in different ways, the common practice in Europe implies delivery of energy to the consumer from some other (often more expensive) producer. That is, it can oblige a generator to increase generation on one side of the bottleneck, and another generator to decrease generation on the other side, compensating both accordingly [6]. The grid operator is forced to assume those costs and include them as congestion management costs. Countertrading[1], on the other hand, refers to the possibility of compensating foreign generators (or consumers) for adjusting their output (or demand), to tackle congestion by using cross-border exchange.

The data used in this paper to evaluate those costs has been obtained from ENTSOE transparency [7]. It must be pointed out that the data available differs greatly in quality and granularity from country to country and from year to year. Furthermore, the data provided by some countries, for example Germany, even differs from the data provided in the country by internal sources, see data provided in Reference [8].

3. Assumptions and Research Method

The main assumption in this work is that the bigger the share of non-dispatchable energy sources, wind and solar power plants, in gross electricity production, the higher are congestion management costs.

To investigate the correlation, the data from ENTSOE's central collection and publication of electricity generation, transportation and consumption data and information for the pan-European market [8] were explored, as well as from the Publications Office of the European Union. The latter publishes the annual statistical pocketbook "EU energy in figures" [10].

The scope of this work is limited to the countries of North-West Europe, as it is shown in Fig. 1.

[1] There is some unclarity in the definition of countertrading depending from the source [9]. The authors decided to use the definition presented in reference [6].

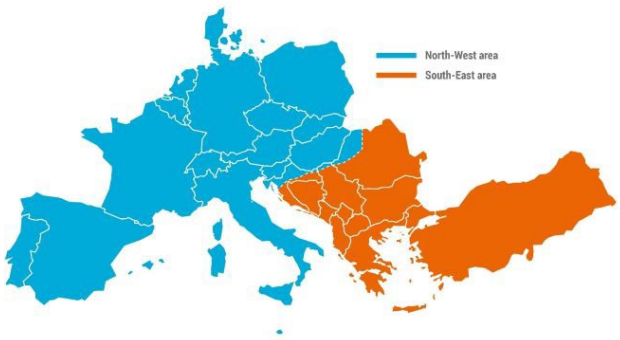

Fig. 1. System Separation in the Continental Europe Synchronous Area on 8 January 2021 – update (image from ENTSOE [7])

ENTSOE provides data on electricity generation by forms and by years from 2000 to 2020. As the target criteria, the congestion management costs themselves and then those costs related to the amount of electricity consumed and to the installed capacity were analyzed.

Among the countries from North-West area, the following countries were selected for the analysis: Germany, Spain, France, Italy, Austria, and Poland. There is more complete dataset provided by these countries.

It should be noted that the application of some statistical indicators for correlation analysis was not possible, since reliable data on costs was available only for five years so far (2015-2020). That is why, the comparison in the next section is given only in the form of diagrams, to show tendencies and identify similarities.

The table below summarizes the data which were taken into account during the analysis.

Table I. –Datasets analysed

Electricity production	Costs
• Gross electricity generation per country [TWh] • Share of wind and solar production [%] • Installed capacity of electric generators [MW] • Share of wind and solar capacity [%] • Total electricity consumption [TWh]	▪ Total congestion management costs [k€] ▪ Available data for re-dispatching costs [k€] ▪ Available data for countertrading costs per country [k€]

4. Preliminary Results

4.1 General Trends and Notes

First of all, it should be noted that the analyzed countries vary greatly in gross electricity production, as it is shown in Fig. 2. For example, Germany and France, each produce at least twice as much electric energy as any other country among the selected ones. The analyzed countries also vary

greatly in the share of non-dispatchable RES, as it is shown in Fig. 3. These two parameters were key to find the expected correlation, therefore it made impossible to compare the data of countries between each other. Also, the characteristics of the power grids in each those countries were too specific to be able to draw general conclusions. Therefore, it was decided to compare only the data of every country with itself in different years, to avoid inconsistencies.

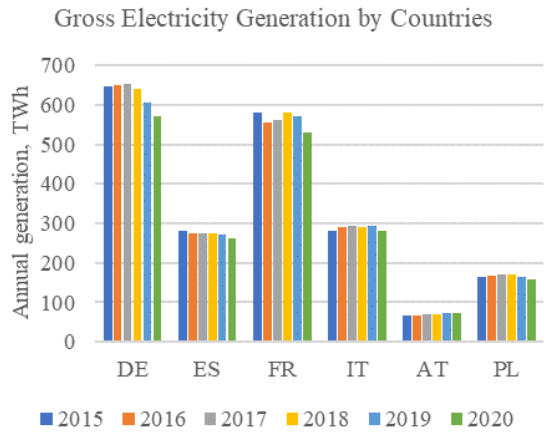

Fig. 2. Comparative levels of gross electricity generation by countries

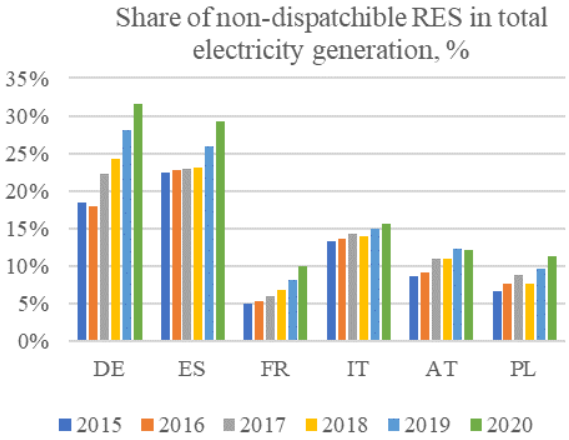

Fig. 3. Share of renewables in the electricity generation

Even being those countries different from each other in terms of energy generation and share of renewables, some general tendencies are clear. The first observation is that the production of electricity was declining over the past years for all countries except Austria. This is a known fact; for some countries such as Germany it can be explained by extensive investments in energy efficiency measures and some increase in the energy import, see Table II.

Table II. – Energy import [Mtoe] per country

	Energy import [Mtoe]					
	2015	**2016**	**2017**	**2018**	**2019**	**2020**
DE	3,18	2,44	2,39	2,73	3,45	4,11
AT	2,53	2,27	2,52	2,41	2,24	2,11
PL	1,24	1,21	1,14	1,19	1,54	1,77
ES	1,29	1,88	2,04	2,07	1,61	1,54
FR	0,86	1,71	1,82	1,17	1,34	1,68
IT	4,37	3,71	3,69	4,06	3,78	3,42

A second observation is that for non-dispatchable renewables, both installed capacity and their share in electricity generation were stably growing in all the countries observed.

4.2. Analysis of the Costs Versus Share of Non-Dispatchable RES in Generation and Installed Capacity

The first analysis was done to identify the correlation between the congestion management costs and the share of renewables for all the selected countries. From those countries, only the results for Germany, Spain and Austria are provided as figures, just as example of the three different patterns observed.

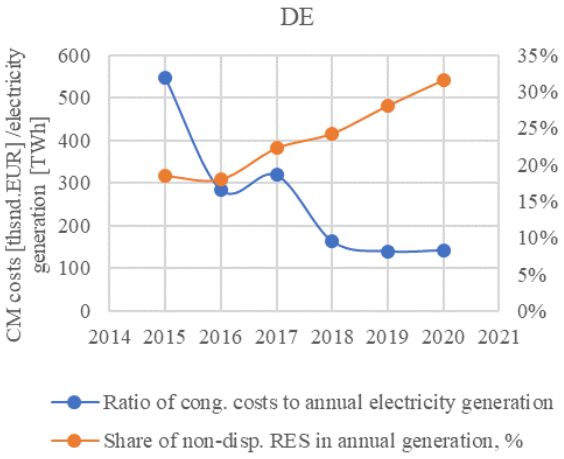

Fig. 4. Case study Germany

In Germany, the congestion management costs decrease over time, while the share increases, see Fig.4.

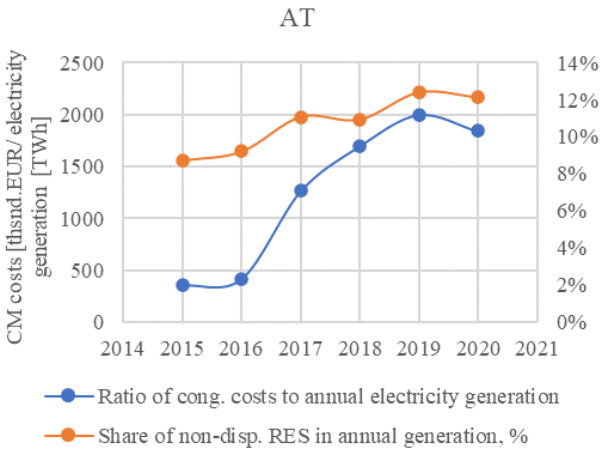

Fig. 5. Case study Austria

Among the selected countries, only Austria demonstrates a clear correlation between the congestion management costs and the share of renewables, see Fig. 5. For the other countries, only a loose correlation was found.

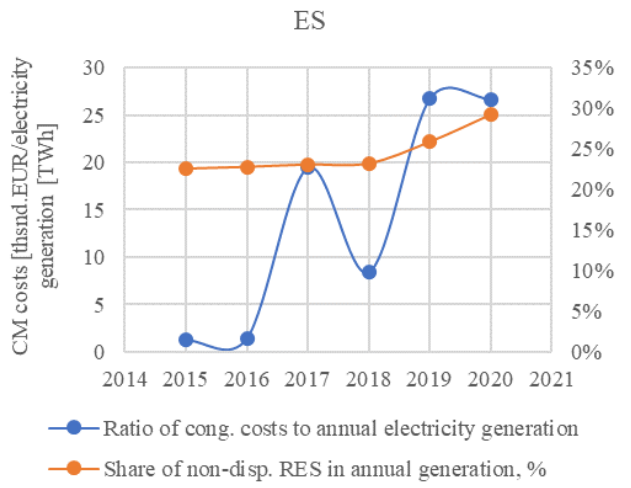

Fig. 6. Case study Spain

For Spain the costs increase together with the share of renewables, but fluctuate greatly, see Fig. 6. France shows a very similar pattern like Spain. Similar results were obtained while comparing congestion management costs versus the installed capacity of wind and solar generating facilities. The capacity predictably grows, while the costs may either grow or decline and fluctuate in a wide range.

Even if the common perception is that the increase of the share of non-dispatchable RES also increases the grid management costs, the available data do not clearly support with evidence this perception. It can be stated that at least this is not the only factor affecting that. A possible reason for this can be found in the lack of reliable data of grid congestion costs or in changes of accounting policies in the different countries, which leads to some incoherencies in the data provided. The data available in the ENTSOE transparency platform has separate data for re-dispatching and countertrading costs. Some countries, like Germany and Austria have both components which are proportional to each other. Others, like Italy are addressing only one component. Poland has reduced its congestion management costs by more than 90% in 2017, which can only be explained by a change in its internal policy and/or regulations on its data gathering after 2015. All those factors have been considered in the conclusions of this paper.

4.3. Analysis of the Costs versus Total Electricity Production

In the light of the inconclusive results provided by the first analysis a second analysis was performed, where congestion management costs were contrasted with the overall electricity consumption in every country. To derive the total consumption, the import of electric energy was also considered, despite that it comprises less than 1% for most countries (except Italy), see concrete data in Table II.

In this case, again, there is some loose correlation, for example in the case of Germany and Austria, this correlation is shown in Fig. 7 and Fig. 8 respectively.

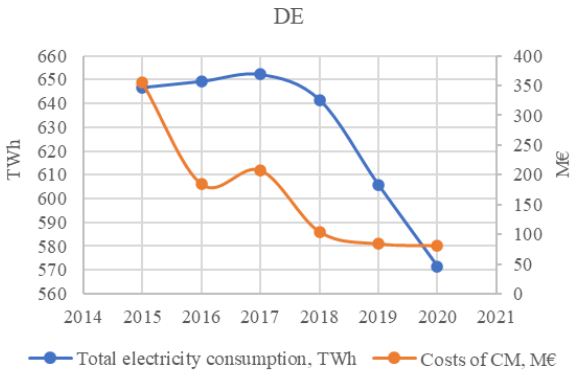

Fig. 7. Case study Germany

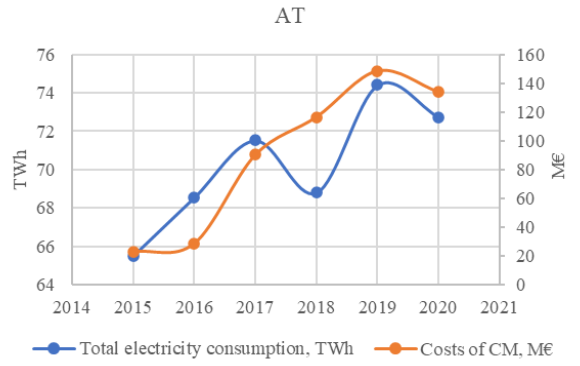

Fig. 8. Case study Austria

The rest of the analyzed countries do not show that correlation, however, again as in the first analysis, those countries have not provided sufficiently complete data set for ruling out any correlation.

Conclusions

This paper has provided material for researchers dealing with the investigation of grid congestion management costs. Two analyses of the available data were performed. The first one was dealing with the effect of non-dispatchable RES in the grid congestion costs. The second one was dealing with the effect of the gross electricity consumption in the increase of grid congestion management costs.

The overall goal of this research work was to reveal the correlation between share of non-dispatchable RES and congestion management costs by using different energy performance indicators. It is found that non-dispatchable renewables have a contribution to the problem of congestion in electric networks, this pattern is clear for countries like Austria, Spain and France, but this influence cannot be clearly modeled with the available data on congestion management costs. The costs are also affected by the total electricity consumption, as seen in countries like Germany and Austria. In the case of Poland, no clear relation was found with neither RES share nor gross electricity consumption, since the available data sets were not complete.

The real problem to perform that kind of needed analysis is the lack of reliable data for the grid congestion management costs, despite of the effort of ENSOE to provide transparency in this area. Due to this lack of data and the inconsistency in the available data, it was no possible to create a mathematical model to prove the expected correlation. Further research is needed in this area to provide mathematical models for forecasting the effect on grid congestion costs due to the increase of the share of non-dispatchable RES.

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References

[1]. S. Huang, Q. Wu, Z. Liu and A. H. Nielsen, "Review of congestion management methods for distribution networks with high penetration of distributed energy resources," IEEE PES Innovative Smart Grid Technologies, Europe, Istanbul, Turkey, 2014, pp. 1-6, doi: 10.1109/ISGTEurope.2014.7028811.

[2]. K. Van den Bergh, D. Couckuyt, E. Delarue, W. D'haeseleer, Redispatching in an interconnected electricity system with high renewables penetration, Electric Power Systems Research, Volume 127, 2015, Pages 64-72,

[3]. R. A. Verzijlbergh, L. J. De Vries and Z. Lukszo, "Renewable Energy Sources and Responsive Demand. Do We Need Congestion Management in the Distribution Grid?," in IEEE Transactions on Power Systems, vol. 29, no. 5, pp. 2119-2128, Sept. 2014, doi: 10.1109/TPWRS.2014.2300941.

[4]. J. Hu, X. Liu, M. Shahidehpour and S. Xia, "Optimal Operation of Energy Hubs With Large-Scale Distributed Energy Resources for Distribution Network Congestion Management," in IEEE Transactions on Sustainable Energy, vol. 12, no. 3, pp. 1755-1765, July 2021, doi: 10.1109/TSTE.2021.3064375.

[5]. GIANLUIGI, Migliavacca, et al. The innovative FlexPlan methodology to reap the benefits of including storage and load flexibility in grid planning: methodology and regional study cases. Cigre Session 2022, 2022, S. 1-12.

[6]. Von Schemde, Arndt, «Redispatch and Countertrade Costs. The Impact of German Bidding Zones. Final Report,» January 2020. [Online]. Available: https://thema.no/wp-content/uploads/THEMA-Report-2020-01-Redispatch-and-Countertrade-Costs-Impact-of-Germany-Bidding-Zones-3.pdf. [Accessed: 18 January 2023].

[7]. «Electricity Market Transparency,» ENTSOE, [Online]. Available: https://www.entsoe.eu/data/transparency-platform/. [Accessed: 13 January 2023].

[8]. Bundesnetzagenur, «Monitoringbericht 2021,» 2021. [Online]. [Accessed: 18https://www.bundesnetzagentur.de/SharedDocs/Mediathek/Monitoringberichte/Monitoringbericht_Energie2021.pdf?__blob=publicationFile&v=6 January 2023].

[9]. Eifer "Contrasting countertrading mechanisms: market effects between Germany and Denmark West" ENERDAY presentation, April 2021 https://tu-dresden.de/bu/wirtschaft/bwl/ee2/ressourcen/dateien/enerday-2021/ENERDAY2021_Countertrading_PUBLIC_Eising.pdf?lang=de [Accessed: 19 January 2023].

[10]. «EU energy in figures. Statistical pocketbook 2022,» 2022. [Online]. Available: https://op.europa.eu/en/publication-detail/-/publication/7d9ae428-3ae8-11ed-9c68-01aa75ed71a1/language-en/format-PDF/source-search. [Accessed: 13 January 2023]