Plausibility Control of Added Transformer Power to the TenneT NL TCB18 Data

OPEN

Prof. dr. Per J. AGRELL

1 Background

Oxera(2020) argues on behalf of TenneT that :

(i) The asset base of TenneT, including a relatively high share of HV lines (63% of line length) and low share of transformers (4.2%) is source of a disadvantage for TenneT with respect to the output parameter “transformer power”,

(ii) The TSOs in TCB18 that have almost exclusively assets at the EHV level (overhead lines and transformers) represent a category which is incomparable to TenneT, being favoured in this regard,

(iii) TenneT should be allowed to include the transformer power of their underlying substations, owned and operated by DSOs, as output in the benchmarking.

(iv) Data has been collected by Oxera from five TSOs for the transformers in their substations at the HV level, not owned and operated by the TSOs.

The inclusion of assets not owned and operated by operators introduces non-validated data and implies a contradiction to the consistency principle (all outputs relate to the operator evaluated).

This note is a limited validation of the Oxera-TenneT data collection and their model.

2 Data collection

2.1 Oxera

Oxera informally asked to report ‘missing transformer power in their substations, especially at HV level, not owned or operated by themselves. To out knowledge, no specific data call was produced, nor were the reporting TSOs asked for any validation of the data. The reported data is merely a sum without any further detail.

Five TSOs reported extra transformers.

2.2 Sumicsid

The consultants, forming a group of economists and engineers, conducted a large search for public data concerning transformer assets, transmission substations and TSO/RTO/DSO assets.

We conclude, also supported by several research groups and their publications, that there exists no public reliable data on transformer assets in Europe. Whereas several interesting and rich information sources have been identified and exploited below for the transmission system networks, including their substations, the transformers remain TSO-level information. Even less information is available for regional and local distribution networks, where data very rarely are as detailed as substation-level.

For this reason, the data collection was made from the types of sources given among the references.

2.3 Method

The validation method concentrates on TenneT NL itself, other reporting (REP) and non-reporting (NONREP) operators.

1. For TenneT, we discuss the existing data and its plausibility.
2. For REP, a validation was made as whether the extra volume reported, in comparison with the validated number and type of substations, correspond to a plausible transmission power for its purpose.
3. For NONREP, a sampling was made to find evidence of HV-resources similar to those for REP that should have been reported for consistency.

3 Technical analysis

Figure 1 shows the situation where a TSO substation (above) at the EHV/HV level is split in transformer assets between the TSO and the DSO. The latter assets can be said to correspond to a network capacity managed by the superior network. Below the network, the DSO operates a series of substations at HV/MV level that are passive. These transformers are cascading from the upper level and have no relevance for peakload management.

The network, including substations with transformers, immediately below the central transmission network (“backbone”) at 300kV-450kV is also call sub-transmission network. It is frequently operated at 70-132 (110) kV and serves to transport electricity to the distribution networks, where radial lines are drawn from substations stepping down from e.g. 110 kV to 10-33 kV. Smaller stations in the DSO networks then stepdown to the voltage delivered to the final load, 0.4-1.0 kV.

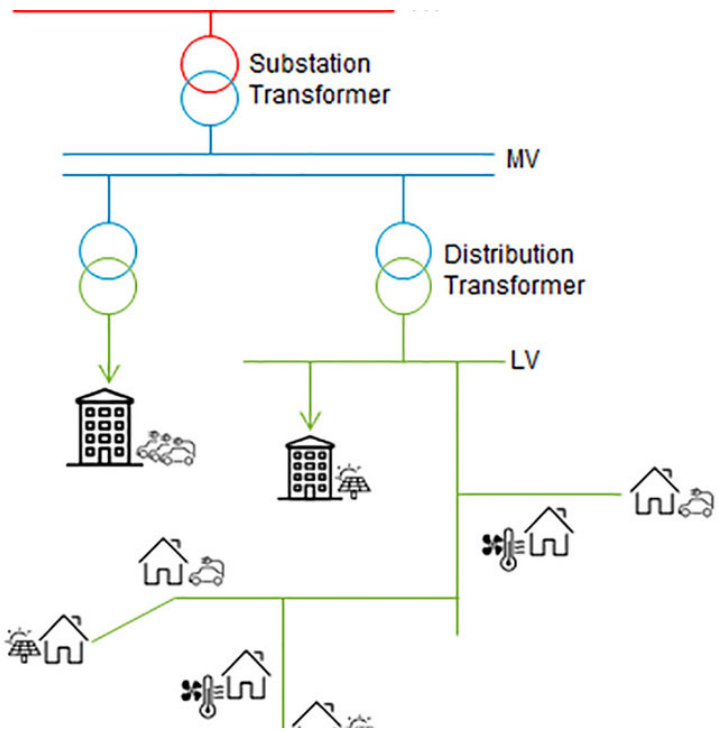

Figure 1 Substation with TSO-DSO transformers and DSO substations in line.

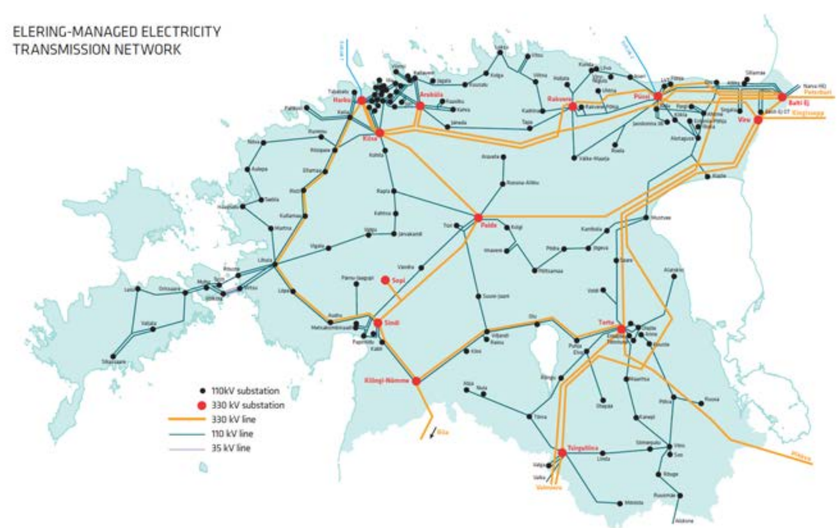

Figure 2 Grid map Elering, 2021. Reported substations in red.

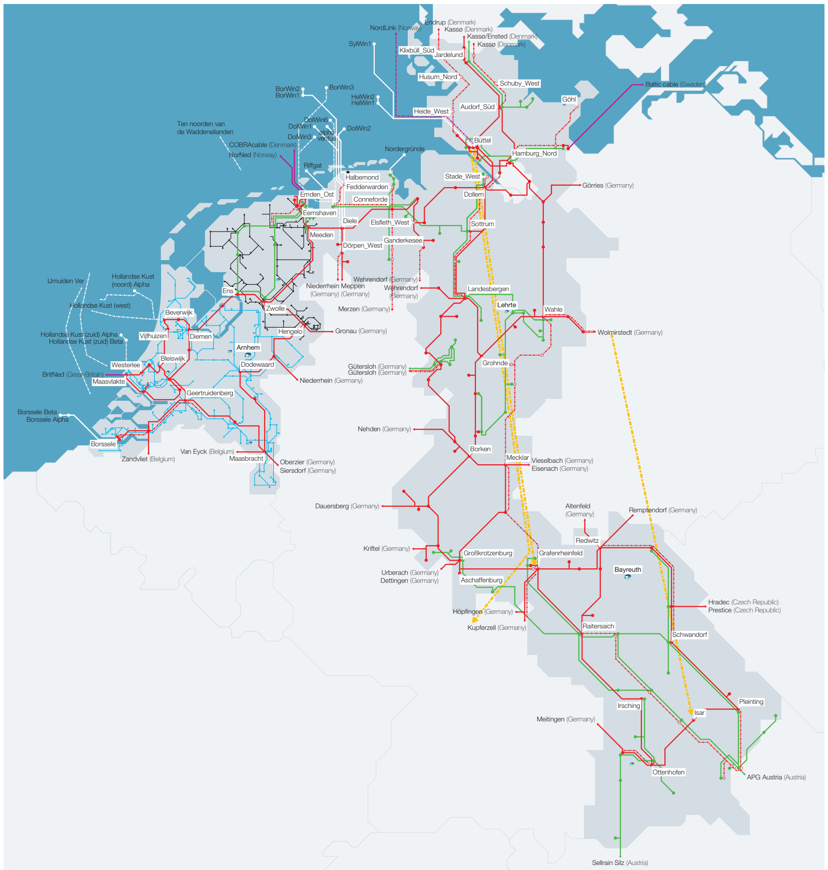

Figure 3 TenneT (NL and DE) network map, TenneT 2021.

4 Data validation TenneT NL

The additional data delivered for TenneT NL is limited to the overall installed transformer power 42,032 MVA. There is no information concerning for the types, ages, investment cost or voltage levels of the transformers, nor of their substation locations. The ENTSO data concerning TenneT NL does not include these assets (ENTSO, 2021) as they are owned and operated by DSOs.

Thus, as-is the data from TenneT cannot be validated as it does not contain any verifiable references of technical or economic nature.

Data for some of the DSOs (Liander, 2021) show the organisation of sub-transmission stations in their service area, as well as their management of some capacity problems in part of it.

In **Error! Reference source not found.** (confidential) below we list the number of transformers and substations reported and validated in TCB18, as well as the number of substations reported by ENTSO in their maps and SciGrid data. A number of substations (#Subs.rto) do not have any TSO-transformers assigned to them in TCB18, we denote these (validated) assets as RTO substations. For TenneT, there are 270 of such stations.

Remains to find whether the residual RTO stations for TenneT correspond to a comparable base, or whether part of the stations are more equivalent to DSO stations. Consider the data presented in Table 1 for the reporting TSO and two added NONREP. Two key indicators are (i) the installed capacity and (ii) the coverage of the substation.

Table 1 Net transformer power and HV linelength (km) per RTO substation.

Country	netTP_nSub.rto	LineHV_nSub.rto
	145	52
	439	142
	161	59
NL	156	21
	329	52
	194	25
	28	22

As seen, the average installed capacity for an RTO station is 207 MVA, roughly corresponding to 4 transformers 220/33 of each 50 MVA. The case of LT indicates that the substations are not comparable, as will be discussed below. The installed capacity for TenneT is at 75% of the mean suggesting that part of the stations may be different.

Second, the length of the HV network covered has been evoked by Oxera (2020) as an argument for correction. Indeed, if the RTO substations are covering an unrepresented HV network, then this will be seen as the circuit length HV per RTO station. The mean coverage is 57 km per RTO-station. Including all TSO in the analysis leads to a higher value (67 km), but one could argue that some TSO do not even report RTO stations without TSO assets included. Again, LT is revealed as having a considerably lower coverage, which is linked to the fact that the stations reported and the additional power in fact correspond to the total installed power and all substations for the DSO below. However, the same applies to TenneT: 21 km is a DSO-type density. Correcting for the density to the mean value gives an expected number of 105 RTO substations for TenneT.

The reasonable additional transformer power for RTO functions is therefore obtained as 207 MVA/RTO substation multiplied by 105 stations, i.e. 21,773 MVA.

Combining with the validated TSO data for TenneT NL (39,990 MVA), this yields a total TSO+RTO capacity of 61,763 MVA to be considered.

5 Results Data validation NONREP

Among the nonreporting TSOs, we found convincing evidence for some TSOs to report additional resources.

5.1 Svenska Kraftnat

The Swedish TSOs turns out to be an outlier with respect to transformers: very few transformers, only EHV, but many substations to manage. In fact, SVK is the only operator with a lower TSO-controlled capacity than the annual peakload. They also operate a network where the overall coverage (circuitkm per substation) is very high, 82 km (25 km for TenneT).

The reason is technical: the Swedish network is organized in TSO, RTO and DSOs, where five regional transmission system operators (RTO) handle transmission from 132 to 70 kV. They are also the owners-operators of the substations to their levels. The RTO are subject to incentive regulation and benchmarking, their data is verifiable for overall capacity, but not to the exact locations of the substations. However, detailed validation shows that the RTO-substations (without SVK assets) all contain either RTO transformers or, for the larger cities, DSO-owned assets. Adding the relevant transformer capacity as suggested would add 30,401 MVA to the output for SVK.

5.2 Statnett

The technical organization of the Norwegian electricity grid is analogous to the situation in Sweden: TSO, RTOs and DSOs. The RTOs are subject to specific regulation and provide validated data for their assets and capacity. For consistency we add the RTO capacity of 16,466 MVA to the Statnett installed capacity.

5.3 National Grid (NGET)

The largest UK TSO, National Grid, has almost exclusively EHV line assets and transformers in their asset base (98.2 % in Oxera, 2020). Nevertheless, detailed verification of the kits in certain substations (named Grid Supply Points) for the DSOs Eastern Power Networks, South Eastern Power Networks and London Power Networks show existence of transformers owned and operated by the DSOs on the premises. NGET has correctly not reported these assets, but in analogy with the 110 kV transformers likely present in the TenneT data, this could be added. However, the addition is not crucial to the evaluation and the added assets have no relevance for the techno-economic evaluation, offering merely cascading step-down transformation.

6 Results Data validation REP (excluding TenneT NL)

The reporting TSO largely comply to the call for the specific data, with the exception of Litgrid.

6.1 ADMIE

The Greek TSO ADMIE publishes additional network information on capacities and substations, differentiating between generation, DSO, RTO and line stations. The additional data is found to be plausible with respect to the structure and residual capacity of the network.

6.2 Fingrid

Fingrid operates a network with meshed TSO structure as in Figure 4 with the particularity of a parallel 110 kV power system. However, there are a number of RTO-type stations, corresponding to a high coverage and represent non-cascaded TSO assets. The data for the DSOs are validated, but the exact relevant volume cannot be verified. Given the plausible level of the indicators we find the reporting acceptable.

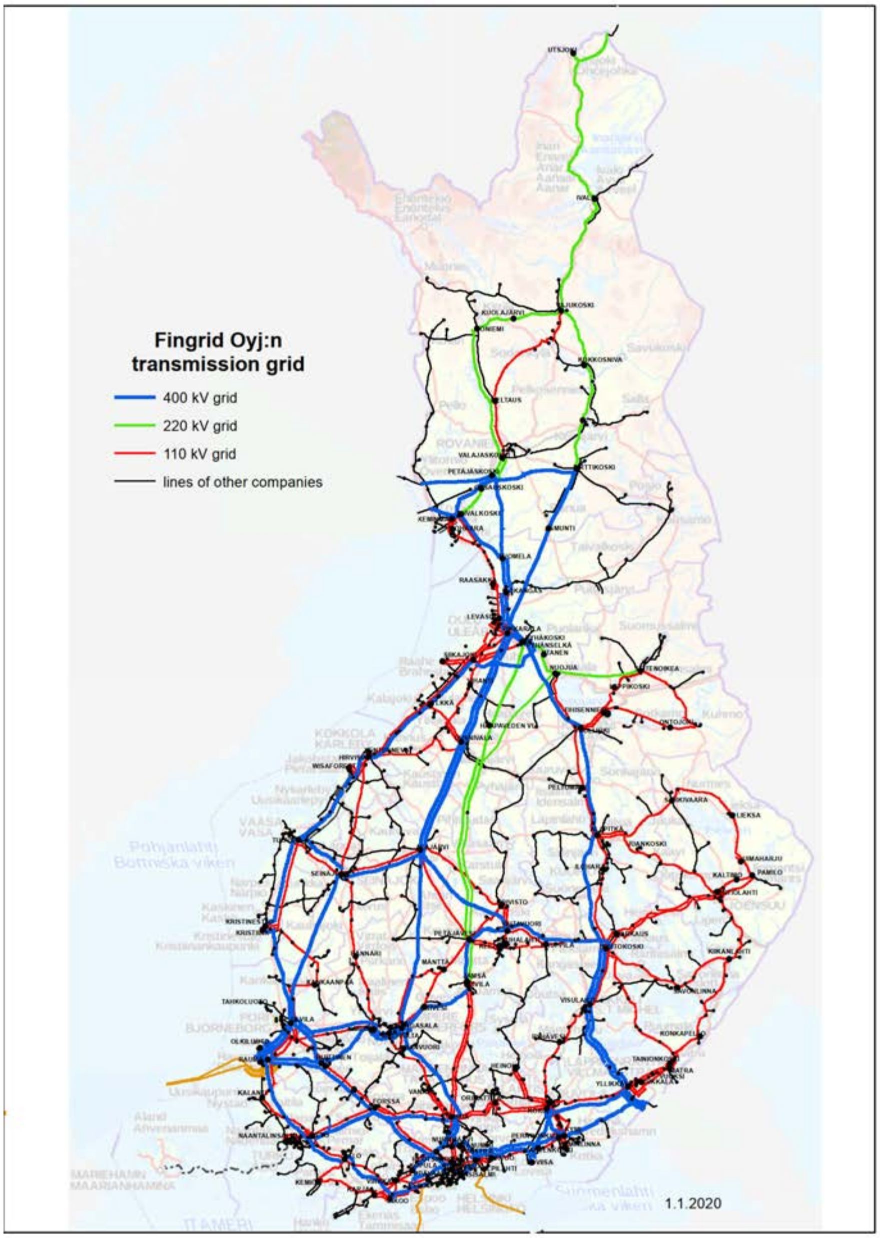

Figure 4 Fingrid network and DSO (black), Fingrid, 2020.

6.3 ELES

The Slovenian TSO has a small EHV backbone (see Figure 5) and 75% HV assets. This is naturally reflected in the number of ENTSO substations (9) for the EHV network, complemented with *x* RTO stations. All indicators (average MVA per station, coverage per station, structure) are close to the mean values and there is no reason to doubt the reporting.

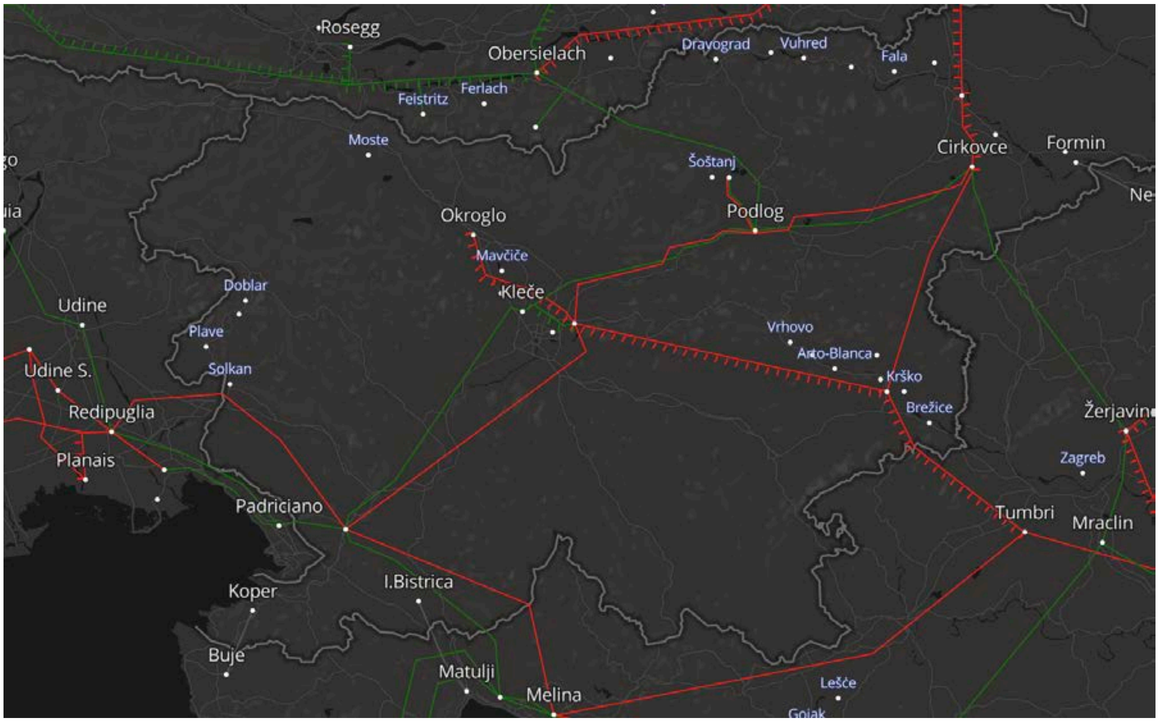

Figure 5 ELES grid (ENTSO-E grid map, 2021).

6.4 Litgrid

The TSO in Lithuania reports a high number of substations, whereof 16 corresponding to the ENTSO EHV network above. As indicated in Figure 6 below, the structure for the underlying 110 kV network is clearly of DSO-character with a multitude of small stations, equipped on average 28 MVA per station (corresponding to e.g., one typical 110/10 kV transformer).

The added installed capacity appears to be excessive, including some assets of DSO-type. An adjustment here has no impact on the analysis for TenneT and we therefore conclude that the reporting is likely incomparable without further data on any correction.

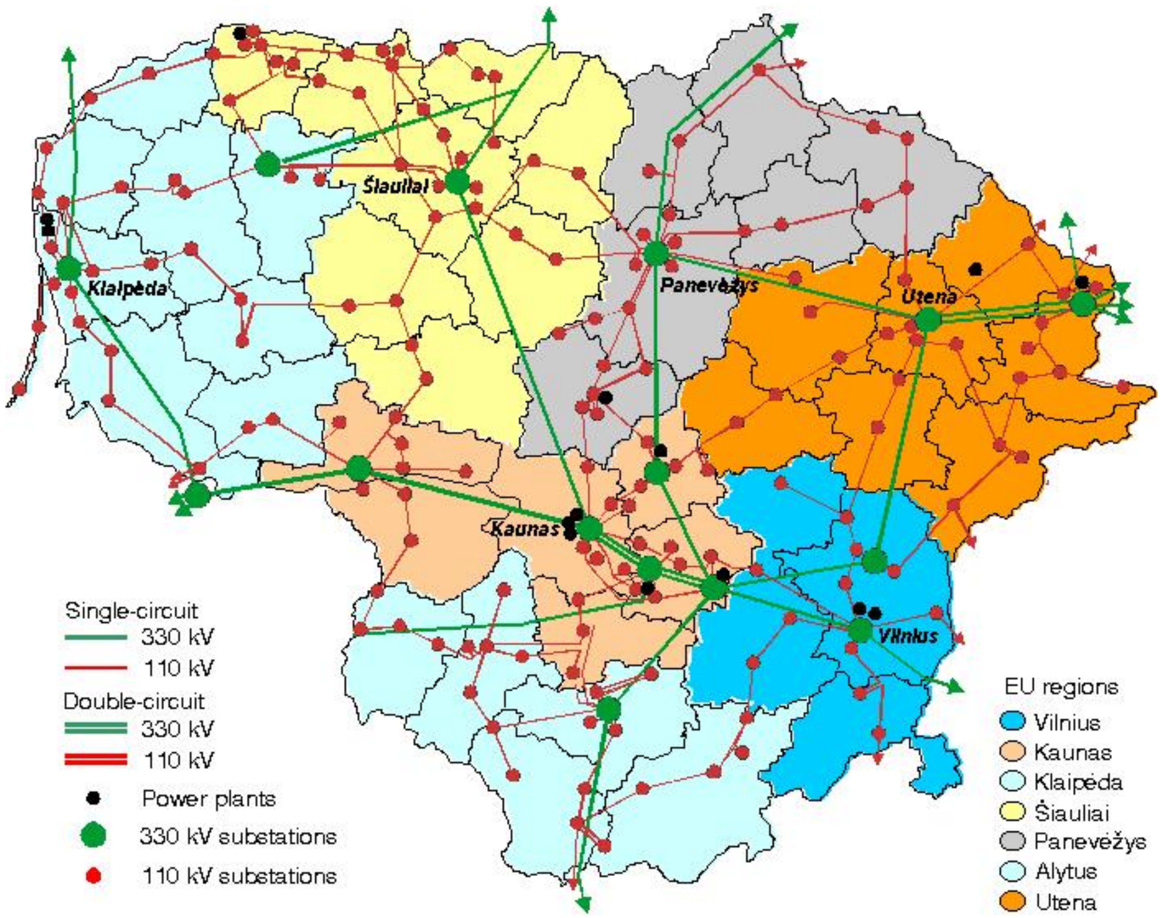

Figure 6 Litgrid TSO network with EHV substations (green) and HV/DSO substations (red). (Geni.org, 2021).

7 Results DEA score TenneT

To estimate the impact of the additional transformers, with the corrections and additions above, we perform two simulations. The reference set is identical to TCB18.

a. Score without cost estimate for the added RTO-transformers (open red circles in Figure 7). This corresponds for TenneT to a case where the added Totex for the added transformers would would be equivalent to the same proportional change in NormGrid.

b. Score with a cost estimate for the added RTO-transformers (filled red circles in Figure 7). Since we lack any other precision than the total capacity, we use the median value from ACER (2015) of 9,500 EUR per MVA for the investment, adding 3% for the operating costs.

The graph in Figure 7 shows the score for TenneT as a function of the total value of the output yTransformer_power in MVA. As seen, the score is stable up until about 65,000 MVA, at which point the score monotonously increases to about mean efficiency.

The score including the cost estimate slightly decreases until 65,000 MVA, this is merely an effect of the assumption on the ratio cost to NormGrid value. Since TenneT until 65,000 MVA has a binding target in NormGrid and Connection Points, the increase in transformer power is not changing the virtual output sufficiently but marginally increasing cost for the cost parameters in ACER(2015). However, we recall that the cost effect is irrelevant here: no information exists for the TSOs about the transformer costs, other assumptions may give marginal increases in score.

As the recommended overall transformer capacity amounts to 61,763 MVA, the conclusion is that there is no validated change in relevant score for TenneT by these assumptions.

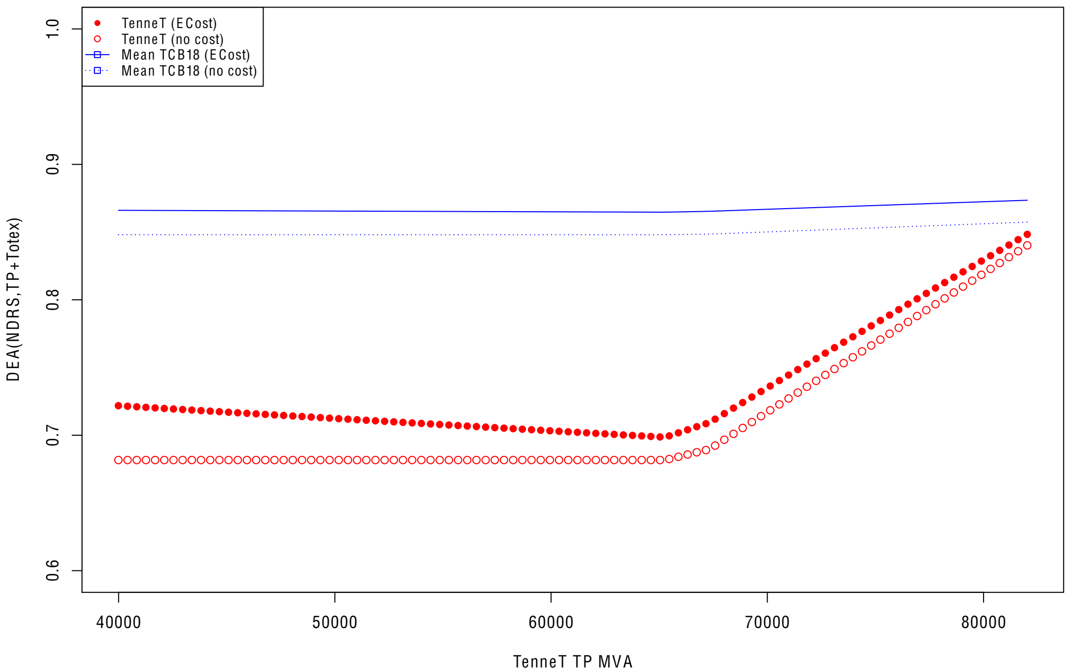

Figure 7 DEA score for TenneT with Oxera data, including and excluding cost-estimate for the added DSO transformers.

8 Simulation with smaller reference set (37804)

Below we report the results from another simulation with a reduced reference set and adjusted outputs for the year 2017. All other technical parameters are unchanged (NDRS, outliers). Here, the ‘level playing field’ is created by removing HV assets completely from the comparison, considering heterogeneity of substation ownership and technical system role at the HV-level.

The reference set contains 13 TSOs with only their EHV assets included.

Table 8-1 Results special run 37807-4.

Parameter	*n*	mean	St.dev
DEA-score, 2017	13	0.930	0.115
Score TenneT, 2017		0.790	
#peers	5		
#outliers	4		

9 Relevance of the Oxera proposal

Irrespective of the outcome of the simulation in this note, a strong caveat must be made to the logic of the proposal in Oxera (2020).

The TSO-benchmarking is based on the correspondence of inputs (cost) and performance (outputs) to gauge managerial efficiency. A specific output (NormGrid) corresponds to the network assets per se, corrected for age and ownership. Another output, capacity provision, is aiming at capturing the cost effects from simultaneously using assets of different age, location and dimension to offer energy transport capacity to the users. One outcome variable for grid provision is peak load (MW), but its inclusion requires a careful analysis as it is the result of randomness; a stochastic variable. In TCB18, a deterministic proxy for grid provision was chosen: total installed transformer power (MVA).

As explained above, adding transformer power for underlying networks is not correlated to Peakload since it amounts to adding cascading transformers. These assets are not subject to the same risks, costs and control requirements as TSO-EHV assets that are continuously used to maintain system adequacy. The current data collection shows that opening the option to report HV (110 kV) transformer assets that are not owned and operated by the TSO is merely decreasing the validity and precision of the benchmarking without offering any advantages in terms of diminishing heterogeneity (see the comments on REP and NONREP data). Indeed, for the countries where good techno-economic data exist in well-defined system borders (RTOs in Scandinavia), the outcome is still irrelevant as these RTOs are benchmarked and evaluated on their own merits for their own assets, not mixed with any TSO-equipment.

This being said, the call for recognition of the specificity of the HV/EHV shares across TSOs is not without merit. However, rather than *adding unvalidated data* to an existing data base with the obvious consequences, we are more in favor of *reducing the reference set to comparable assets* to create the level playing field. Consequently, the proposed approach to reduce the reference set only to include operators with a similar share of HV/EHV assets appears defendable under the assumption that they share some unobserved cost structure.

10 Conclusions

Our partial validation of the Oxera (2020) extra data collection of HV transformers connected to TSOs has been made with very limited access to information. Only a full data collection, based on a solid data specification and accompanied with means to identify and validate the specific resources can fully eradicate all uncertainty. However, as we note here and elsewhere, the idea of gauging units on the assets of third parties is managerially flawed and against system science.

With respect to the three levels we find:

1. The TenneT transformer data appears exaggerated, likely including DSO-type transformers that are irrelevant in this context.

2. The non-reporting countries include some obvious examples (SVK and Statnett) of sub-transmission operations that have not been reported. In this particular data, adjusting the transformer power to include the RTOs does not change the result for TenneT.

3. Except for Lithuania, the reporting countries are have not shown to be submitting incomparable data. For Lithuania and TenneT, the reports are exaggerated. In this particular data, changing the data for Lithuania does not impact the assessment of TenneT.

Quantitatively in terms of score, we find that the score of TenneT is stable for the plausible range of transformer capacity in the comparable TSO(EHV) + RTO (HV) range up until 65,000 MVA.

11 References

ACER (2015) ACER Report on Unit Investment Cost Indicators and Corresponding Reference Values for Electricity and Gas Infrastructure. Final report. https://www.acer.europa.eu

DSO-type data, e.g. for Liander; https://twiav.nl/nl/energie/liander_elektriciteitsnetten.htm?x=114343&y=515818&n=9

ENTSO (2021) TSO interactive map, https://www.entsoe.eu/data/map/

ENTSO (2021) TSO dataset, https://www.entsoe.eu/publications/statistics-and-data/#entso-e-on-line-application-portal-for-network-datasets

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SciGrid (2021) https://www.power.scigrid.de/pages/osm-data-coverage.html

Sumicsid and CEER (2019) *Project TCB18 Individual Benchmarking Report*, V1.0, 2019-07-25.