***Application of a scaling down method to study long term effects of Wind and Solar on the FRENCH TSO Tariff***

Thomas Verderi, RTE/CIRED, + 33670472675, thomas.verderi@rte-france.com

Sandrine Bortolotti, RTE, sandrine.bortolotti@rte-france.com

Laurent Lamy, CIRED, laurent.lamy78@gmail.com

## Overview

Despite the current pandemic, countries keep working on energy transition. In France the government has set ambitious goals for Distributed Renewable Energy Resources (DER) in a plan called the PPE (Programmation Pluriannuelle de l’Energie). For instance solar capacity is set to rise from 10.4 GW in 2020 to 44 GW in 2028. Onshore wind capacities will go from 17.6 GW up to 34.7 GW in 2028.

Most of those new capacities will be connected to the French DSO grid (Distribution System Operator). However, though these DER will not be directly connected to its grid, the TSO (Transmission System Operator) will still be affected. DSOs are connected to the TSO at one of the 4000 High Voltage/Mid Voltage substations. From the TSO point of view, the demand of a DSO at one of these substations is its residual load, defined as local consumption minus local production. By changing the local production, the diffusion of DER will change the shape of residual loads. Some substations will withdraw less energy and will instead inject energy into the TSO grid. For those substations, the peak of the residual load might be an injected peak and not a consumption peak anymore.

These changes of the shape of the load have economic consequences on a variety of aspects including dimensioning costs, grid operation costs, as well as TSO tariffs. The transmission grids and related pricing methods were designed under the assumption that these substations would act as consumers, not producers. The current tariff design is based on a correlation between peak power and total energy withdrawn. Following this principle, a bill that a client pays to the TSO depends mostly on the energy it withdraws from the TSO. With the anticipated DER capacity, this correlation might not exist anymore which raises concern about the viability of the current tariff regarding the TSO revenue.

This paper studies the impact of DER on the residual loads of the DSO connected to the French TSO in 2030. To do so, it uses a scaling-down model using data from the French TSO long-term adequacy report to estimate the long term local residual loads at each of the TSO substation. The impact of those DER is studied by varying the installed capacity of solar and wind energy and their location. The article demonstrates the impact of the DER diffusion on the shape of the residual load by studying several variables that are used to design the French TSO tariff. Finally, a simple reinforcement cost model is used to evaluate the order of magnitude of the economic impact on the cost for the TSO, and the current tariff structure the change in revenue.

## Methods

This paper estimates the long term local residual loads at each of the French TSO substation in 2030. To do so, it uses a scaling down method that takes national data from the French adequacy report and scales down separately the local loads and the local production at each of those substations. The national prospective load is split between each substation using hourly historic metered consumption data. This method has been testing using data from 2012 to 2016 to estimate the local loads of 2017 and 2018. It gives a R² mean of 0.86 for 2017 and 0.84 for 2018. It is quite close to others studies in the literature of load estimation as in [1] or in [2].

The wind and solar production is then downscaled using load factors that vary regionally according to the location of the substation. Ground based solar plants and onshore wind location depend on the technical potential of the area and the available capacity dedicated to DER[[1]](#footnote-1) at the substation. Solar roof panel location depends on the number of housing and companies connected to the substation. To study the impact of DER on local loads, we then vary the total installed capacity of onshore wind and solar capacities from 8 GW to 65 GW. In addition, we study five scenarios in which we vary a decentralization parameter from 0% to 100% by 25% step. This parameter corresponds to the proportion of solar capacity that is installed as rooftop panels. We refer to the reference scenario as the scenario where the decentralization parameter takes the value of 50%.

Several residual load indicators that are used to build the French TSO tariff are then analyzed, including:

* The sum of withdrawn energy: the kWh withdrawn by all the consumers connected to the TSO. If it is equals to the energy consumed, it means that all the energy requirement is met by the TSO.
* The sum of subscribed power: the maximum of the load curves withdrawn by the consumer.
* The sum of injected energy: consumers that also produces energy may inject their production on the TSO if they produce more than they consume at a given time.
* The sum of injected power: it is the maximum of the power injected by the DSO.

If the injected power becomes higher than the withdrawn power, the power grid must adapt to this new constraint. This can be done using the suited flexibility. Here, we will study two extremes scenarios: the case where the TSO reinforce the substation capacity to accept all the injected power and the case with systematic curtailment. It means that we will study two more indicators:

* The sum of “dimensioning” power: it is the maximum between the subscribed power and the injected power.
* The sum of the energy that is curtailed: this is the scenario where we curtail the energy as soon as the power injected goes higher than the subscribed power.

Finally, a simple reinforcement cost model of the substation is used to evaluate the order of magnitude of the economic consequences for the TSO between today and our scenarios.

## Results

In our reference scenario for the 2030 PPE capacity, the sum of national energy withdrawn will be reduced by 50 TWh compared to 2016 which represents almost 10% of the energy withdrawn from the TSO in 2016.

For all the scenarios, the energy withdrawn decreases with the installed solar capacity. In our reference scenario, a rise of 15 GW of solar capacity induces a diminution of around 10 TWh of the energy withdrawn whereas the energy injected rises 3 TWh. Most surprisingly, we do not see a saturation yet: even with high installed capacity the energy withdrawn continues to decrease with new capacity. The impact of the parameter of decentralization is more significant as the capacity rises. In 2030, decentralizing 10% more of the solar capacity diminishes the energy withdrawn three times more for the PPE capacities (around 47 GW) than for the current trend capacities (around 19 GW). The effect of solar energy on the subscribed power is less significant: solar production does not allow to reduce the sum of subscribed power in any of our decentralization scenarios.

While the production profiles are quite different, wind has similar effect to solar power. 1 GW of additional wind capacity has the same effect as 1 GW of additional solar capacity on the energy withdrawn in our reference scenario. Once more, we do not observe any asymptote in the decrease of the energy withdrawn. Here, 15 GW of additional capacity provoke an increase of the injected energy of almost 17 TWh. Those injections represent a consequential volume of more than half of the wind production. Wind power plants have more impact on the injection peak however; mostly because they are located in areas with fewer consumption than solar. 15 GW more of wind capacity leads to a 10 GW increase of injected power, which is notably higher than the most centralized PV scenario. This rise leads to a bigger impact on the dimensioning power.

The cost model shows that the reinforcement cost mostly depends on the installed capacities. Costs vary from almost 50% between the current trend and PPE capacities for the reference scenarios. In current trends of installed capacity scenarios, total cost does not vary depending on the decentralization parameters because solar capacities are too low to see an effect. However, choice of decentralization parameters makes a huge difference for the PPE capacities. Decentralizing half more compared to the reference scenario decreases the reinforcement cost by 10%.

## Conclusions

The down scaling method allows us to study locally different scenarios of electricity mix. In the article, we use it to assess the impact of several electricity mixes on French TSO tariff revenue. We show that the installed capacity and the decentralization parameter have a tremendous impact on three indicators: the energy withdrawn, the energy injected and the dimensioning power. Both those parameters depend on the political objective and the societal choices. If the tariff structure remains the same, we can expect less tariff revenue for the TSO while the need for reinforcement will likely increase.

## References

[1] A. Gerossier, T. Barbier, et R. Girard, « A novel method for decomposing electricity feeder load into elementary profiles from customer information », *Appl. Energy*, vol. 203, p. 752‑760, oct. 2017, doi: 10.1016/j.apenergy.2017.06.096.

[2] F. M. Andersen, H. V. Larsen, et R. B. Gaardestrup, « Long term forecasting of hourly electricity consumption in local areas in Denmark », *Appl. Energy*, vol. 110, p. 147‑162, oct. 2013, doi: 10.1016/j.apenergy.2013.04.046.

1. This capacity is issued from the S3RENR. It is a document that presents the French regional strategy to develop the energy transition. It specifies the capacity dedicated to DER at each substation. [↑](#footnote-ref-1)