REGIONAL POWER SYSTEM FLEXIBILITY MANAGEMENT UNDER AN ENERGY TRANSITION SCENARIO: THE CASE OF FRENCH REGION OCCITANIE

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Overview

In order to fullfill the Paris Agreement climate goals, many countries, including France, have set ambitious targets to decarbonize the electricity sector. Besides energy sobriety and efficiency, these targets include a significant development of renewable and decentralized energy sources such as wind power and solar photovolaïcs. Along national support of Variable and Renewable Energy capacities (VRE), regional governances have also proposed their own energy transition scenarios. This is the case of south-located French region Occitanie, which has an important potential for wind and solar power. Using this resource advantage, the region aims to become the first French region with a positive energy balance. Thus, in 2017, the region has, in collaboration with the national *Agency for the environment and energy management* (ADEME), published a precise scenario for its energy transition pathway [1]. Named REPOS 2050, this scenario notably includes a reduction of the local electricity consumption by 39% compared to the 2015 level, respective increases of 430% and 1081% for terrestrial wind and solar power, and the deployment of 3 000 MW of offshore wind capacities by 2050. If realized, this scenario will transform the Occitanie regional power system, switching from a centralized, wholesale market dominated to a a decarbonized, decentralized and digitalized one [2].

VREs output being intermittent, variable and hardly predictable, a necessary reflexion on power system flexibility must be conducted. Indeed, this new paradigm of decentralized and intermittent electricity production requires the power system as a whole to be able to cope with rapid changes either in load or generation. At the scale of regional power systems, congestion management also appears to become one the key issues emerging along the energy transition [3]. Thus, creating Local Flexibility Platforms (LFP) is perceived as a promising way to facilitate the development of VREs [4-5]. Noticeably, LFPs would also become tools that help postpone capital expenditures in grid infrastrucures, reduce operational costs of the considered power system, and foster the creation of new economic opportunities for participants. [6-9].

In this paper, we first assess the flexibility requirements induced by the REPOS 2050 scenario, and then propose an linear optimization method for the regional management of flexibility sources. Precisely, our aim is to quantifiy the contribution of each flexibility source (including conventional generation, power exchanges with other regions, and storage) to the regional power system flexibility, and determine the overall cost of flexibility under the assumptions made in the REPOS 2050 scenario.

Methods

Our methology includes two main components. The first part is the quantification of the flexibility requirements that the achievement of the REPOS 2050 scenario would induce. To achieve this, we use the half-hourly Residual Load (RL^D) (Equation (1)) curve as a proxy for the power system flexibility requirements. The RL^D will then be used as the flexibility demand in the optimization model.

(1) $RL^D = Consumption - (Prod_{onshorewind} + Prod_{offshorewind} + Prod_{PV})$

To obtain such a flexibility demand under the REPOS 2050 assumptions, we simply project the expected half-hourly consumption and VRE generation for the year 2050. Taking the year 2015 as a reference, we first create a time-series of consumption that account for the expected 39% reduction. Then, we use the 2015 local load factors of VREs and the expected capacities for the year 2050 to generate onshore wind and solar PV generation time-series. Since offshore wind capacities are not present in Occitanie in 2015, we chose to model offshore wind generation time-series using an Ornstein-Ulhenbeck process [10] calibrated with United Kingdom offshore wind recorded data. Finally, we use Equation (1) to generate a Residual Load time-series for Occitanie region (Figure 1).

The second component of our methodology is to build a merit-order based cost linear optimization model of flexibility sources. The model is presented in Equations (2) to (5). Our Residual Load offer (RL^O) function includes the following flexibility sources : utility scale batteries (q_t^{BAT}), bioenergy (q_t^{BIO}), Pumped-Hydro Storage (q_t^{PHS}), conventional generation (q_t^{PIL}), nuclear generation (q_t^{NUC}), hydropower (q_t^{LAC}) and market exchanges (q_t^{MKT}).

(2) Objective function : $\min C_t = \sum_{i=1}^{k} q_t^i * c_i$

(3) Balancing constraint : $RL_t^D = RL_t^O$

where $RL_t^O = q_t^{BAT} + q_t^{BIO} + q_t^{PHS} + q_t^{PIL} + q_t^{NUC} + q_t^{LAC} + q_t^{MKT}$ and c_i is the cost of flexibility source *i*.

(4) Capacity constraints : $\forall\ i\ \in I :\ q_{min}^i \leq q_t^i \leq\ q_{max}^i$

(5) Storage constraints : $SOC_{min}^i \leq SOC_t^i \leq SOC_{max}^i$

Where SOC_t^i is the state of charge of bidirectional flexibility source *i*.

Capacities and costs of flexibility sources are calibrated with Occitanie data (accessible from the grid operators open-data platform *Open Data Réseaux Energies)*. Note that for the Market exchanges flexibility source, the average wholesale market price of year 2015 is taken as the cost/sell price. We use python package Pulp to solve the model for each half-hour of projected year 2050.

Results

The projection of REPOS 2050 assumptions on Occitanie Residual Load is presented in Figure 1.

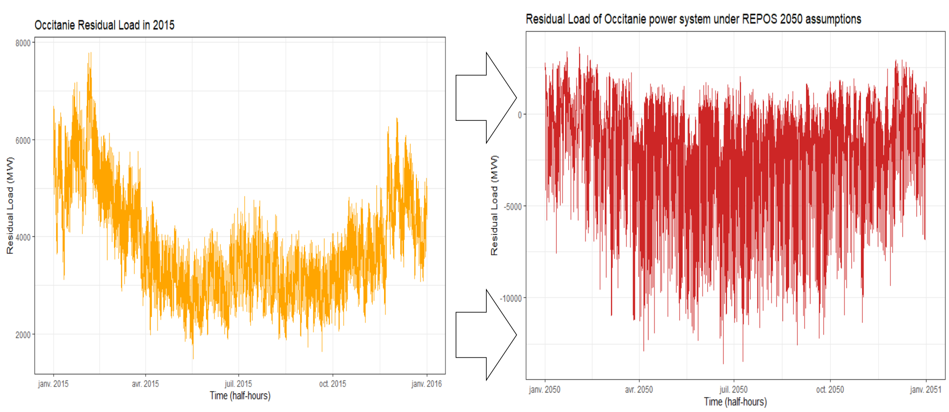

Figure 1. Projection of Occitanie Residual load using assumptions from the REPOS 2050 scenario

After solving the model with baseline costs and capacities parameters, we find that the most used flexibility sources are hydropower, nuclear and market exchanges sources. The descriptive statistics of the flexibility total cost are provided in Table 1.

Min	1rst Quart.	Median	Mean	3rd Quart.	Max	Std. Dev
0	23040	53276	73419	103560	340500	65741

Table 1. Descriptive statistics of Occitanie flexibility total cost under under baseline REPOS 2050 assumptions.

Conclusions

In this paper, we have proposed a new regional flexibility management mechanism. We have calibrated an optimization model of flexibility sources with Occitanie REPOS 2050 scenario assumptions and found that the most used flexibility sources are conventional hydropower, nuclear and market exchanges under baseline cost and capacities parameters. The overall cost of flexibility for year 2050 would be 998 132 630 €, and the DSO would earn a total of 13 471 224€ by selling the electricity surplus generated in Occitanie. It is important to mention that our modelling framework can be used to investigate various possible flexibility development scenarios.

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