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Overview

Nowadays, the energy system is facing major challenges as important trends push for its transformation. As a main driver, fighting climate changes urges governments to implement efficient climate energy policies. Therefore, in order to strongly reduce CO2 emissions, large scale integration of variable renewable energies (VREs) is being encouraged.

However, the power system was developed as a vertical system with a centralized electricity production together with an extensive transmission grid which transports electricity to the final consumer. Thanks to this architecture, the system was robust and reliable. On the opposite, VREs production is intermittent and less predictable. As a result, with high share of VREs, the system needs to be more flexible than before. Hence, energy security is a key issue to the success of climate-energy policies [1].

New flexibility options have arisen in order to achieve the security and the reliability of the power system: Demand Side Management, storage technologies, VREs curtailment. However, using all these options will not be enough to integrate a high share of VREs. Indeed, renewable energies potential are unevenly distributed in Europe but also within a country. Therefore, electricity generation will highly increase in some regions and thus, it will increase power flows exchanges with the neighbouring regions. Hence, the existing transmission grid would face congestion which will result in important investments such as reinforcements or new lines.

These new situations lead to question the role of the transmission grid in case of large scale integration of VREs and how can the grid be considered as a new flexibility option for electricity management.

Methods

In order to answer these questions, a new module called EUTGRID (EUropean – Transmission Grid Investment and Dispatch) has been developed and coupled with the long-term energy model POLES[2]. Based on inputs from POLES such as power plant capacities and mean production costs per technology, EUTGRID performs an hourly power dispatch on typical days and gives back to POLES information on VREs curtailment or hourly production.

The European transmission grid plays a crucial role for power exchanges but with more than 10,000 nodes it is too important to be implemented in EUTGRID. Thus, Europe has been divided into 96 nodes with several nodes per country [3]. This representation differs from long-term energy models which have only one node per country [4], [5]. Together with the implementation of a DC-loadflow, this cutting helps to get more realistic power flows and capture the impact of a large-scale integration of VREs [6].

EUTGRID includes also a grid investment mechanism which allows to consider transmission grid expansion thanks to the coupling with POLES model. It uses nodal prices as a signal to detect and reduces congestion in the transmission grid [7] [8]. Hence, it goes through the most congested lines and increases their capacity (either HVAC or HVDC). However, it is only allowed if the annualized reduction of the total costs covers the annualized investments in less than the return on investment (ROI), which in our case is assumed to be ten years[9].

Results

A “2°C scenario” is being used as a scenario with large scale integration of VRES where the role of the European transmission grid can be analysed. In this context, 2 cases were compared: (S-1) a “2°C scenario” with investments in the transmission grid and; (S-2) a “2°C scenario” with no investments performed after 2030. Indeed, future investments in the network are already planned until 2030 [10].

In the two different cases, the total share of VREs reaches 46% (VREs only include solar and wind production). However, in (S-1), total investment needed in the transmission grid equals to 478 billion euros while in (S-2), it is limited to 179 billion euros which is in line with the value announced by ENTSOE in [10] (ie “*Total investment costs for the portfolio of projects of pan-European significance amount to approximately €150 billion*”). During the period 2015-2030, 320 GW of HVAC and 38 GW of HVDC are being added while during the period 2030-2100, 138 GW of HVAC and 134 GW of HVDC.

However, when looking at different parameters such as curtailment production, energy not distributed and mean production costs, it can be underlined the positive impact of transmission grid. Curtailment production increases up to 2.7% of total energy produced in 2100 in (S-2). However, adequate investment in the transmission grid helps to reduce RES spillage as it reaches only 1.18%. Similarly, energy which is not distributed appears when total share of VREs exceeds 33% and reaches in 2100 1.5% of the total demand. On the opposite in (S-1), the situation occurs when total share of VREs exceeds 43% and reaches in 2100 0.15% of the total demand. Because the energy not distributed is very expensive, one can observe that mean production costs increases greatly in (S-2): in 2015-2020, mean production costs amount approximately 24€/MWh and in 2090-2100, it exceeds 340€/MWh. In (S-1), the transmission grid helps to keep mean production costs around 80€/MWh.

Finally, when comparing installed storage technologies (ie hydro-pumped storage, batteries, vehicle-to-grid and adiabatic batteries) and their associated production in the 2 scenarios, in (S-2) up to 35 GW more are installed. During the period 2090-2100, when total share of VREs is at its highest point, the total energy produced by storage technologies in (S-2) exceeds by 35% the amount produced in (S-1). This shows that the transmission grid also competes with the storage technologies.

Conclusions

The coupling of two different models: EUTGRID, a power dispatch which includes a realistic grid investment mechanism based on nodal prices and POLES, a long-term energy model enables to analyse the role of the transmission grid in a scenario with high share of VREs. Investing in the transmission grid increases the power flows between the regions and thus, reduces curtailment of VREs production and the energy not distributed to customers. As a result, mean cost of the energy mix does not greatly increase. It has also been shown that transmission grid competes with the storage options as it reduces its production.

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