A methodology for dynamic procurement of secondary reserve capacity in power systems with significant vRES penetrations

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***Abstract*— The European pathway to carbon neutrality indicates strong investments in variable renewable energy sources. Demand-side and variable renewable players rely on forecasts to participate in day-ahead markets closing between 12 and 37 hours ahead of real-time operation. As such, the further from the real-time operation those forecasts are provided, the higher their errors and the uncertainty. Deviations from the market schedules are balanced using real-time reserves. Traditionally, transmission system operators (TSOs) use a symmetrical procurement of up and down reserves based on the expected demand. This work considers the computation of a dynamic up and down procurement of secondary capacities by considering the expected deviations, using the day-ahead programmed and expected dispatches of variable renewables, demand, other technologies, and the cross-border capacities. The study uses operational open data from the Spanish TSO from 2019 to 2022. The proposed methodology allows increasing the usage of the up and down secondary capacities by almost 13% and 8%, respectively, freeing up 11% of the allocated resources, on average.**

***Index Terms*– balancing markets, dynamic secondary capacity procurement, forecast uncertainty, programmed dispatch.**

I. INTRODUCTION

The 2030 European National Energy and Climate Plans indicate sector coupling and a high investment in variable renewable energy sources (vRES), such as wind and solar photovoltaic (PV) technologies to achieve the goal of a carbon-neutral society by 2050 [1],[2]. Increasing penetrations of vRES are raising the usage and costs of reserves across Europe due to their stochastic production profile [3],[4]. The duck curve effect originated from high penetration of solar PV is already a reality in several power systems with significant up and down net load ramps (load minus vRES generation). This situation leads to the so-called merit-order effect, which reduces market prices in the case of negative or nearly zero net loads and increases balancing costs in the case of net load ramps [5],[6]. Market participants pay the balancing costs of their imbalances as Balance Responsible Parties (BRPs) [7],[8]. The self-cannibalization effect and the increase in balancing costs originated by increasing penetrations of vRES are obstacles for their market integration without externalities like support schemes [9],[10]. Demand-side and vRES players rely on forecasts to participate in electricity markets. These forecasts tend to have higher uncertainty, especially in time horizons farther from the real-time operation [8],[11].

The European Single Day-ahead Coupling market is the most liquid electricity market, closing between 12 and 37 hours ahead of real-time operation. TSOs use the day-ahead market (DAM) outputs to define the programmed dispatches of each player. After its closure, TSOs have to define the required capacities of the Frequency Restauration Reserves (FRR) needed to cover potential real-time deviations from programmed schedules [12],[13]. While the DAM rules are harmonized in Europe, the rules of balancing markets (BMs) significantly differ among different market zones [13]. Traditionally, TSOs use a symmetrical procurement of up and down automatic FRR (aFRR), also known as secondary reserves, based on the expected demand, as suggested by the European Network of TSOs (ENTSO-E). The Spanish and Portuguese TSOs use a practically symmetrical and an asymmetrical procurement of secondary reserves, respectively [14]. In those secondary capacity markets, participants need to be able to provide an interval of down and up capacity to support this balancing mechanism. So, markets with high penetration values of vRES shall adapt their design according to the stochastic behavior of vRES. These changes to market designs shall integrate vRES and increase the operational efficiency of power systems [13]-[17].

The legislation of the European Commission for regulating the European Internal Market of Electricity (EIME) encompasses measures of market design and harmonization