



# Frequency markets and the problem of predictability

EPRG Working Paper 2220

Cambridge Working Paper in Economics CWPE2306

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## Abstract

Ancillary services markets (ASMs) are gaining higher importance in renewable-based power systems. They, however, remain less explored than the energy markets (EMs) of different regions. For limited energy units, such as battery energy storage systems (BESSs), it is vital to investigate the relative predictability of the two markets as suitable bidding hours of a less predictable product are more challenging to identify, thus entailing less certain revenues. This paper develops forecast models of the two markets of three Nordic countries – Denmark, Finland, and Norway – to quantify the difference in their predictability. Frequency containment normal reserves (FCR-N) are considered as a case of the Nordic ancillary service product. The dataset of 315648 datapoints contains three years (2019 – 2021) of their hourly FCR-N, and spot market revenues. Generalized additive models (GAMs) are used to develop week-ahead forecasts using smooth curves of hourly and daily patterns. The forecast allows both inter country – between same markets of different countries – and intra country – between different markets of the same country – comparison. The results show that the FCR-N markets of the Nordic countries are less predictable than their respective spot markets except for the case of Denmark due to its fixed hourly volumes. Moreover, the smoothing curves of FCR-N forecast models differ for each Nordic country despite their similar market requirements. This is in contrast to the Nordic spot markets where the smoothing curves indicate similarity in inter-country market behaviors. Considering market predictability differences in addition to their hourly prices is thus vital for BESS units performing multi-market bidding.

**Keywords** Ancillary services, Spot markets, Forecast, Battery energy storage

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Publication December 2022  
Financial Support BOSS: Bornholm Smartgrid Secured by grid-connected battery systems, contract no. 64018-0618

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