

Electromechanical and Grid Aspects of Wind Turbine Control in Europe and Northern Eurasia

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GOAL OF THE STUDY

This study develops a reproducible framework to compare wind power controllability in the EU and CIS. It links regulatory settings and power system dynamics to assess how grid codes, balancing rules, and reserve activation times affect system stability and efficiency under high wind penetration.

METHODOLOGY OF THE INVESTIGATION

The study compares wind-power controllability in the EU and CIS at two levels: regulatory (grid codes, balancing responsibility, reserve products) and operational (forecast accuracy, activation times, curtailment, balancing costs).

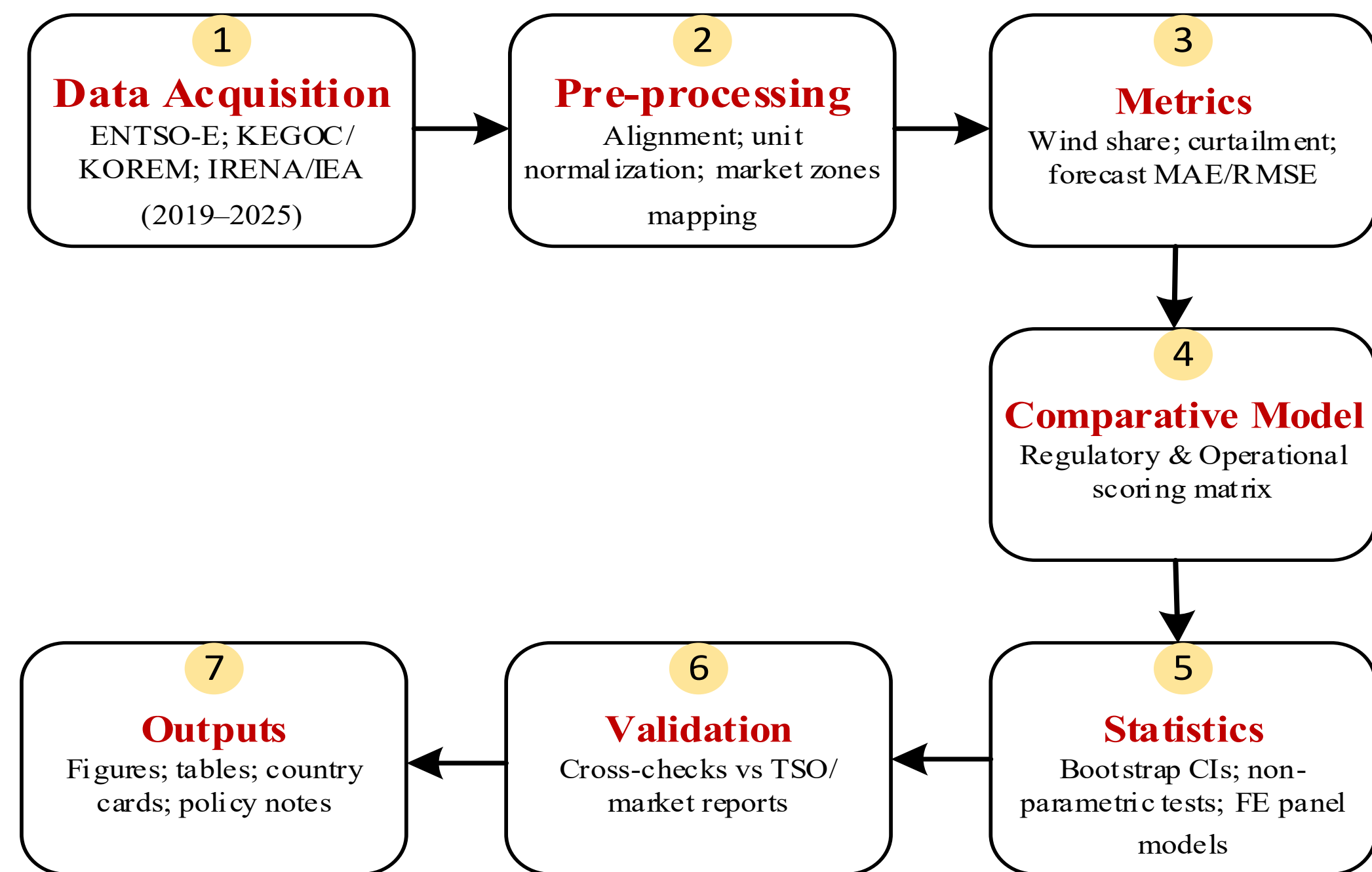


Fig. 1. Methodological pipeline for EU & CIS comparison

MAIN RESULTS FROM THE STUDY

EU systems with standardized FAT values ($aFRR = 5$ min, $mFRR = 12.5$ min) show lower imbalance energy and greater reliance on fast automatic reserves. CIS systems lack unified FAT standards, resulting in slower response and higher imbalance areas. Improved forecast accuracy and shorter activation times jointly reduce imbalance magnitude and balancing costs. The EU's “narrow” control loop ensures faster stabilization, while CIS countries show a path toward convergence through FAT formalization and forecasting improvement.

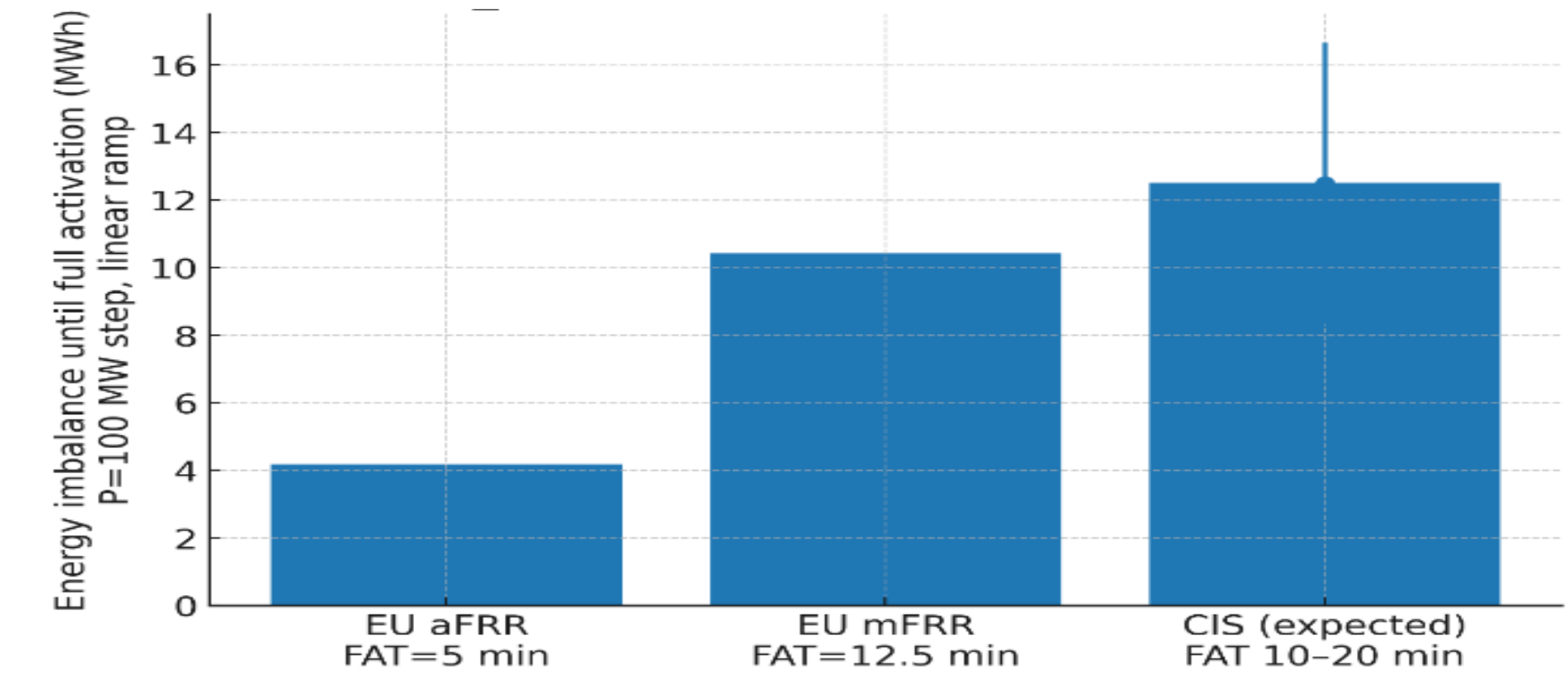


Fig. 2. Comparative Eimb vs FAT (EU verified vs CIS expected range)

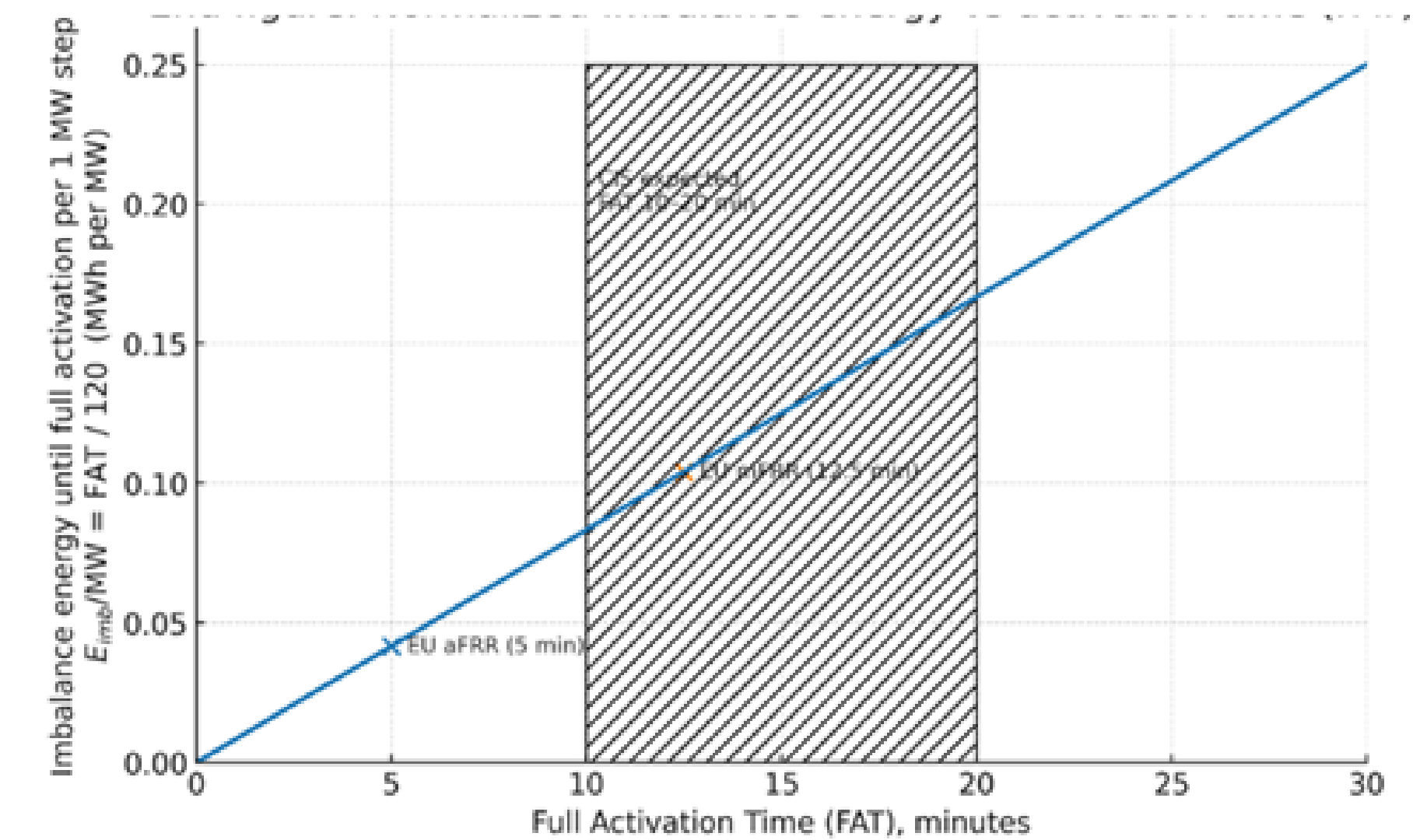


Fig. 3. Normalised imbalance energy vs activation time (FAT)

CONCLUSIONS

A reproducible EU–CIS framework links regulation with system dynamics. Shorter FATs and better forecasts reduce imbalance and costs, enhancing controllability. CIS systems should standardize FATs and improve data transparency.

ACKNOWLEDGMENT

This study is financed by the European Union-NextGenerationEU through the National Recovery and Resilience Plan of the Republic of Bulgaria, project № BG-RRP-2.013-0001.