AI to address operational challenges in short-term RES forecasting

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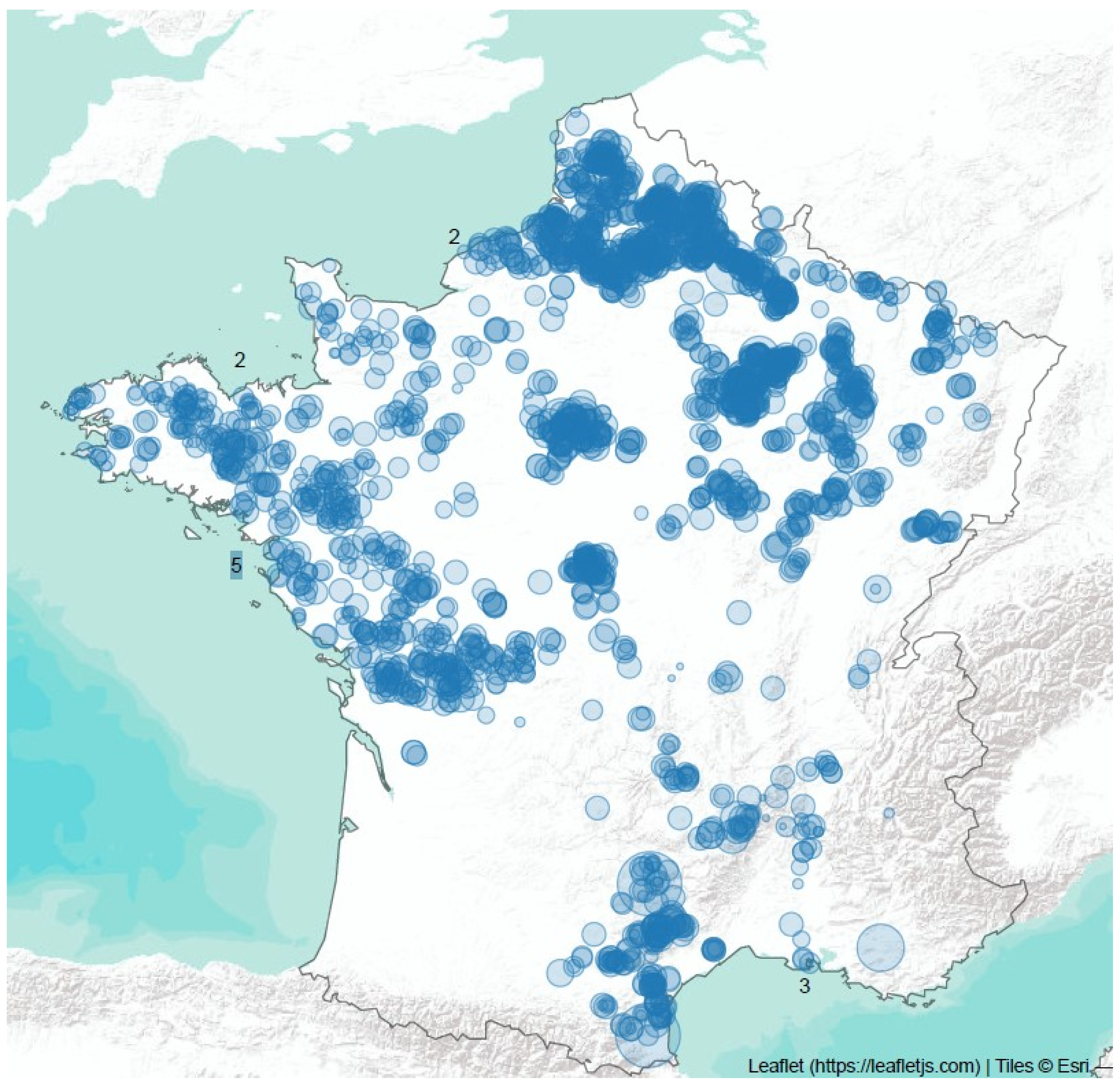
Rte Le réseau de transport d'électricité

Motivation

Transmission System Operators are responsible for maintaining the real-time balance between electricity generation and consumption while ensuring system security. The rapid increase in variable RES has altered the operational conditions under which TSOs perform these missions. From an operational perspective, TSOs must continuously manage the real-time power balance to regulate frequency, and must also manage congestion to respect network constraints. Consequently, TSOs require forecasting tools that are:

- **Informative about uncertainty (probabilistic forecasts)**
- **Resilient to missing data and adaptive to evolutions of the RES portfolio composition**
- **Robust to extreme events**
- **Local (to manage congestion) and national (to regulate frequency).**



Geographical distribution of wind power generation sites.

State-of-the-art

Deep learning models (RNNs, CNNs, Transformers) achieve strong accuracy, but are often **task-specific**, data-hungry, and sensitive to **distribution shifts**.

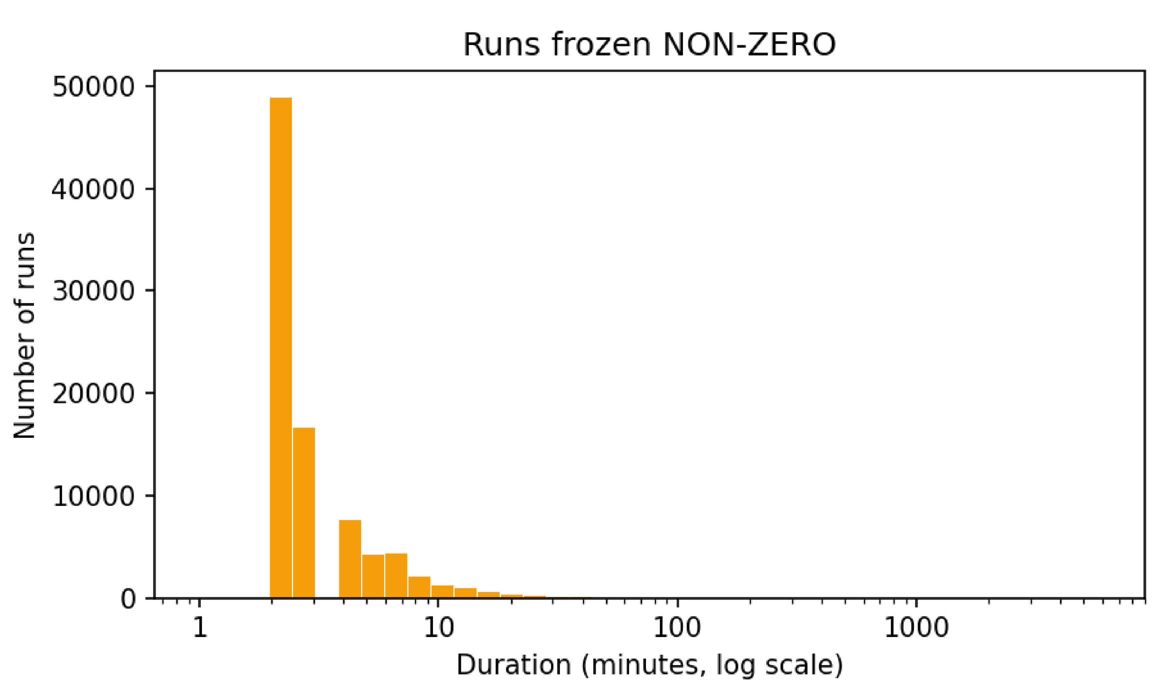
Foundation models offer a path toward **transferable** and reusable forecasting systems, reducing dependence on bespoke models and supporting **digital sovereignty** through shared, adaptable infrastructure.

However, many foundation models rely on attention mechanisms with **quadratic complexity**, limiting scalability for long multivariate time series.

State space models (SSM) provide a structured latent dynamical view of time series, enabling **linear complexity**, robust long-context modeling, and natural handling of missing data.

SSMs are therefore a promising backbone for **scalable, transferable, and sovereign** power-system forecasting.

On the unreliability of data



A (non-zero) run is a sequence of fixed values (excluding 0) that is exactly the same from one step to the next. The figure depicts the redundancies that happen.

More broadly, data used in online scenarios typically consist of **sensor measurements**. At this scale of deployment, these measurements may be inaccurate, biased and may fail to accurately represent the electricity supply.

Acknowledgements

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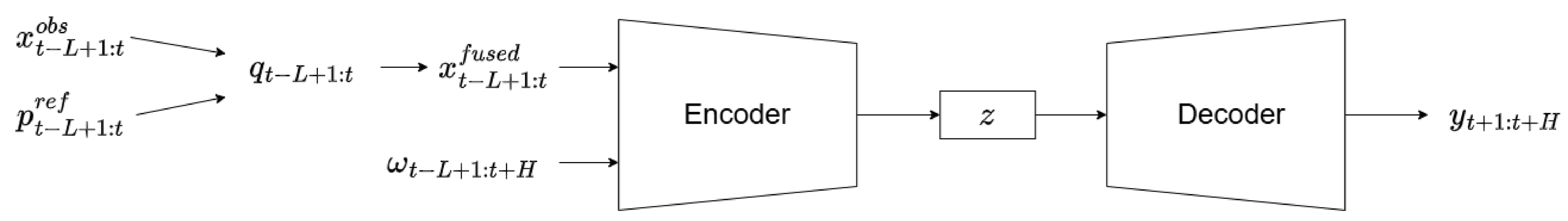
Towards Robust Predictive Models in the Presence of Unreliable Data

A first toy model for robust forecasting with unreliable data used is a variational auto-encoder with quality-based fusion. The objective is to develop a model able to make predictions **without imputation**.



*Overview of the **proof-of-concept** quality-gated latent forecasting model. A local quality network estimates timestep-wise measurement reliability from observed production, and a wind-based plausibility reference.*

For each timestep t, $q_t = Q_\theta \left(x^{obs}_t, p^{ref}_t, |x^{obs}_t - p^{ref}_t| \right)$, with Q_θ a neural network. Then:

$$x^{fused}_t = q_t x^{obs}_t + (1 - q_t) p^{ref}_t .$$

The latent variable parameters (μ_z, σ^2_z) are then inferred from $x^{fused}_t, \omega_{t-L+1:t+H}$ with the encoder so that : $z \sim \mathcal{N}(\mu_z, \sigma^2_z)$.
Finally, the decoder uses z, $\omega_{t+1:t+H}$ so that for each horizon h:

$$(\mu_{t+1:t+H}, \sigma^2_{t+1:t+H}) = D(z, \omega_{t+1:t+H})$$
$$y_{t+h} \sim \mathcal{N}(\mu_{t+h}, \sigma^2_{t+h})$$

Proof of Concept Results

Model	n	n affected	RMSE	RMSE affected
Model Aux	1949	111	0.0503	0.0409
Model Qual	1949	111	0.0474	0.0336

Model Aux is a baseline VAE. *Model Qual* uses the learned quality score to gate unreliable past production values before forecasting. Both models are trained on noisy (frozen data) data with clean targets and evaluated on all test windows and affected-only (frozen data) windows.

Conclusion: This PoC suggests that explicitly modeling measurement reliability can help time-series forecasting models handle degraded sensor inputs.

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