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Deep learning-based multi-output quantile forecasting of PV generation

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Context & contributions

Renewable energy is subject to **uncertainty**.
Probabilistic forecasts are an important tool to equip decision-makers [1].

PV **quantile forecast using** quantile regression [2].

Contributions:

1. A tailored deep learning-based **multi-output quantile PV** forecaster;
2. An **encoder-decoder** architecture;
3. **Weather forecasts** of the **MAR** regional climate model [3];
4. A proper assessment of the quantile forecasts is conducted by using a **k-cross validation** methodology and **probabilistic metrics.**

[1] Morales, Juan M., et al. Integrating renewables in electricity markets: operational problems. Vol. 205. Springer Science & Business Media, 2013.
[2] Koenker, Roger, and Gilbert Bassett Jr. "Regression quantiles." Econometrica: journal of the Econometric Society (1978): 33-50.
[3] Fettweis, Xavier, et al. "Reconstructions of the 1900–2015 Greenland ice sheet surface mass balance using the regional climate MAR model." The Cryosphere 11.2 (2017): 1015-1033.

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Forecasting techniques

Day-ahead models:

- Gradient Boosting (GB);
- Multi-Layers Perceptron (MLP);
- Long Short-Term Memory (LSTM) ;

Intraday models (encoder-decoder [4]):

- **LSTM-MLP** named ED-1;
- **LSTM-LSTM** named ED-2.

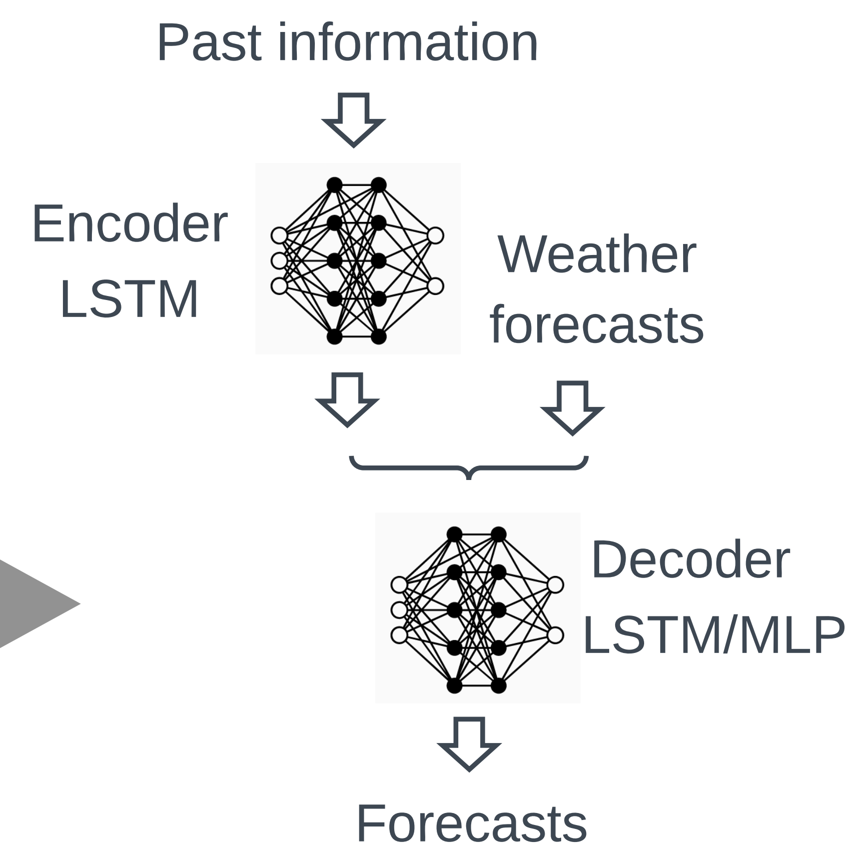

Figure 1: Encoder-decoder architecture.

[4] Bottieau, Jérémie, et al. "Very-short-term probabilistic forecasting for a risk-aware participation in the single price imbalance settlement." IEEE Transactions on Power Systems 35.2 (2019): 1218-1230.

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Quality assessment

Value vs quality:

- **quality**: ability of the forecasts to **genuinely inform of future events** by mimicking the characteristics of the processes involved;
- **value**: benefits from **using forecasts** in a **decision-making** process such as participation to the electricity market. *Ex: in the capacity firming framework* [5].

Focus on **quality** evaluation:

- Continuous Rank Probability Score (**CRPS**) [6]
- Interval Score (**IS**) [6]

[5] Dumas, Jonathan, et al. A Probabilistic Forecast-Driven Strategy for a Risk-Aware Participation in the Capacity Firming Market. Uliège, 2021. Arxiv, [under review for publication in IEEE Transactions on Sustainable Energy]
[6] Gneiting, Tilmann, and Adrian E. Raftery. "Strictly proper scoring rules, prediction, and estimation." Journal of the American statistical Association 102.477 (2007): 359-378.

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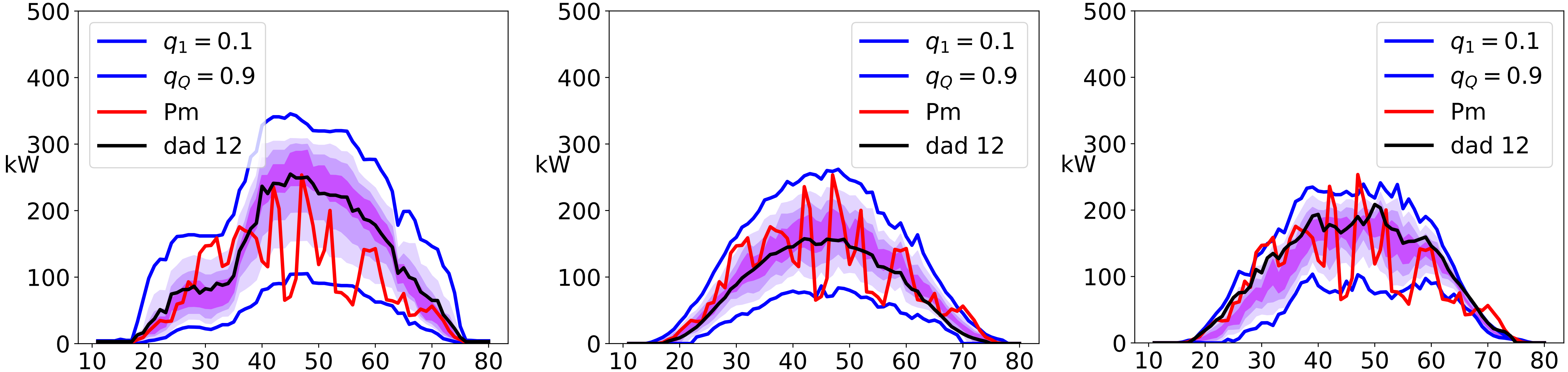
Day-ahead results: point and quantile forecasts



(a) GB *(b) LSTM* *(c) MLP*

Figure 2: Quantiles vs point forecasts of day-ahead models on August 2, 2020.

Red line (Pm) = observations

Black line (dad 12) = day ahead point forecasts

Blue lines (q1, qQ) = 10 % and 90 % quantile forecasts

LSTM achieved the **best results** for both point & quantile forecasts.

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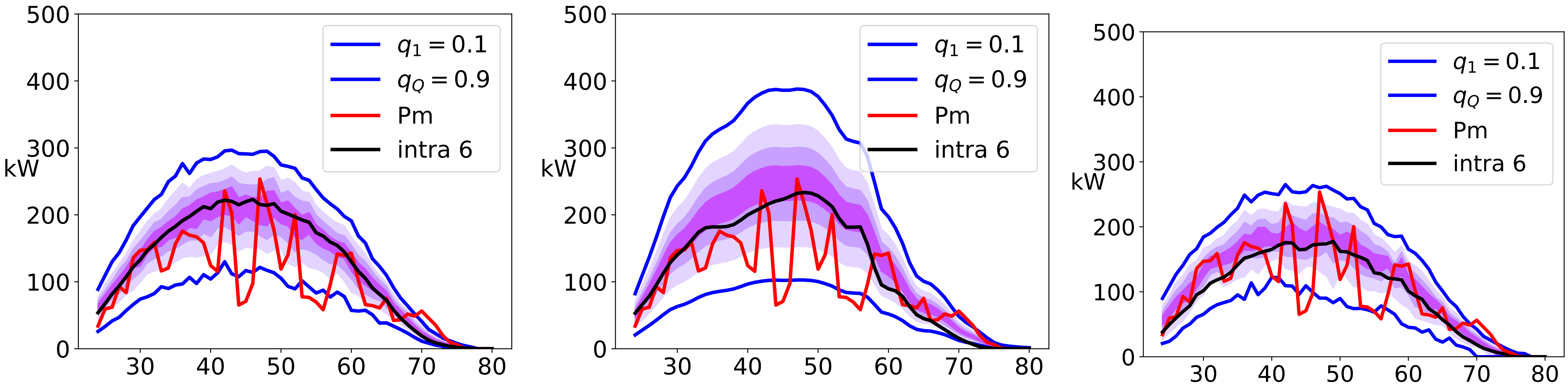
Intraday results: point and quantile forecasts



(a) ED-1 (LSTM-MLP) *(b) ED-2 (LSTM-LSTM)* *(c) LSTM*

Figure 3: Quantiles vs point forecasts of intraday models of gate 6 on August 2, 2020.

Red line (Pm) = observations

Black line (intra 6) = intraday point forecasts

Blue lines (q1, qQ) = 10 % and 90 % quantile forecasts

LSTM-MLP yields accurate and calibrated forecast distributions.

Conclusions & perspectives

Conclusions:

- Day-ahead: **LSTM** achieved the **best results** for both point & quantile forecasts;
- Intraday: **LSTM-MLP** yields accurate and calibrated forecast distributions.

Extensions:

- A PV **scenario approach** based on the encoder-decoder architecture;
- **Deep learning generative models** such as Generative Adversial Networks (GANs), Variational AutoEncoders (VAEs), and Normalizing Flows (NFs) *[under review for publication in International Journal of Forecasting].*