# 31761 - Renewables in Electricity Markets

## Exercise session 5: Verification of renewable energy forecasts

The aim of this exercise session is go through the basics of renewable energy analytics, and to more particularly focus on the verification of forecasts in their various forms. Principles of forecast verification are generic, hence the various approaches discussed can also be used for verifying forecasts for other market quantities (e.g., load and prices). This exercise session relies on Lectures 8 to 11, available at "Lecture notes for 31761 - Renewables in Electricity Markets", as well as on Chapter 2 of the book "Integrating Renewables in Electricity Markets".

### Problem 1: Know your forecasts!

Consider the participation of a 12MW solar power plant in the electricity market. A forecast provider was contracted to provide necessary forecasts for designing and applying various market participation strategies.

1.1 For an optimal-quantile type participation strategy, the nominal level is defined as $\alpha = 0.4$. On a given day before gate closure (say, at noon), the solar power plant operator is provided with the following quantile forecasts for the first 4 market time units of the following day:

$$\hat{q}^{(0.4)}_{t+13|t} = 2\text{MW} \ , \ \hat{q}^{(0.4)}_{t+14|t} = 9\text{MW} \ , \ \hat{q}^{(0.4)}_{t+15|t} = 11\text{MW} \ , \ \hat{q}^{(0.4)}_{t+16|t} = 10\text{MW}$$

What is the predicted probability that solar power generation will be above 9 MW for the market time unit between 1am and 2am of the following day?

1.2 Since the nominal level of the optimal quantile to offer in the market may change depending on estimated penalties for surplus and deficit, the forecast provider generates a number of quantile forecasts with different nominal levels:

$$\hat{q}^{(0.2)}_{t+14|t} = 5.3\text{MW} \ , \ \hat{q}^{(0.3)}_{t+14|t} = 6.9\text{MW} \ , \ \hat{q}^{(0.4)}_{t+14|t} = 9\text{MW} \ ,$$
$$\hat{q}^{(0.5)}_{t+14|t} = 9.7\text{MW} \ , \ \hat{q}^{(0.6)}_{t+14|t} = 10.5\text{MW}, \ \hat{q}^{(0.7)}_{t+14|t} = 10.9\text{MW}$$

Deduce the value of the quantile forecasts to offer in the cases where the optimal nominal levels would be set to $\alpha = 0.37$ and $\alpha = 0.54$

1.3 Based on the quantile forecasts given in 1.2, what is the central prediction interval with nominal coverage of 20%? and of 40%?

1.4 More "traditional" point forecasts are also provided to the solar power plant operator. For this same set-up, the forecast is $\hat{y}_{t+14|t} = 9.2$MW. Is this supposed to tell you anything in terms of probabilities? How to interpret that forecast?

### Problem 2: Verification of point forecasts of wind power generation

You operate a 15MW wind farm and have a contract with 2 forecast providers, *"Guess-it-all"* and *"Just-doing-my-best"*. Considering a given lead time $k$ (say, 12 hour ahead), you receive a number of forecasts day after day (in MW), which you would like to evaluate:

$$\text{Guess-it-all:} \quad \{2,\ 3.5,\ 4.2,\ 5.6,\ 7.4,\ 5.6,\ 6.4,\ 5.3,\ 6.7,\ 8.6,\ 9.3,\ 4.7\}$$
$$\text{Just-doing-my-best:} \quad \{2.6,\ 3.2,\ 3.6,\ 5.9,\ 6.9,\ 5.7,\ 6.3,\ 5.7,\ 6.1,\ 8.7,\ 9.8,\ 8.3\}$$

The corresponding observations are obtained a posteriori:

$$\{1.8,\ 3.9,\ 4,\ 5.1,\ 7.2,\ 6.1,\ 6.7,\ 5.9,\ 6.6,\ 8.3,\ 10.5,\ 6.2\}$$

1.1 Normalize the forecasts and measurements by the wind farm nominal capacity
1.2 Calculate forecast errors and normalized forecast errors
1.3 Evaluate these point forecasts with the common scores that are bias, MAE, and RMSE, calculated both in MW and in their normalized version, i.e., as percentage of installed capacity
1.4 Interpret the value of bias, MAE and RMSE obtained. For instance, do you expect the MAE value to be less than the RMSE one, and why? Can the MAE value relate to an average imbalance? and what about the RMSE one?
1.5 This Problem is also there to help for Assignment 3, since it will be necessary to verify the forecasts to be generated, based on functions written in Matlab or R. Therefore as an implementation exercise in your favourite language, program a function that allows to automatically normalize, calculate forecast errors and determine score values (bias, MAE, RMSE)

**Problem 3: The case of probabilistic forecasts of wind power generation**

You also get probabilistic forecasts from the same 2 forecast providers (*"Guess-it-all"* and *"Just-doing-my-best"*) for your 15MW wind farm. At a given time $t$ and for a given time $t+k$, you receive the following quantile forecasts $\hat{q}^{(\alpha)}_{t+k|t}$, $\alpha = 0.1, 0.25, 0.5, 0.75, 0.9$, from both forecast providers:

| Nom. level | Quant. forecasts (MW, Guess-it-all) | Quant. forecasts (MW, Just-doing-my-best) |
|---|---|---|
| 0.1 | 4.5 | 1.5 |
| 0.25 | 7.5 | 3.75 |
| 0.5 | 11 | 7.5 |
| 0.75 | 13 | 11.25 |
| 0.9 | 14.5 | 13.5 |

The power measurement obtained a posteriori is $y_{t+k} = 12.6$MW.

3.1 Draw the cumulative distribution functions (cdf) for the 2 probabilistic forecasts from Guess-it-all and Just-doing-my-best. How would you also draw the cdf for the actual observation?
3.2 Recall the definition of the indicator variable (permitting to assess the reliability of quantile forecasts) and calculate it for $\hat{q}^{(\alpha)}_{t+k|t}$, $\alpha = 0.1, 0.25, 0.5, 0.75, 0.9$, from both forecast providers. Is that enough to assess the reliability of these forecasts?
3.3 Recall the definition of the Continuous Rank Probability Score (CRPS), and its interpretation based on the cdfs for the forecasts and observation
3.4 Then visually in this case, which of the two forecasters would get the lowest CRPS value?
3.5 Would you be able to calculate the CRPS value by hand, or to program a function to do so in your favourite programming language?