Reply on RC2 – PDF Format

- The abstract indicates that the EMS "is introduced to model the operation of a battery," which sounds like a narrower scope than the wind-battery system described in the paper.

Answer:
Changed wording in abstract to expand scope to wind + battery operation.
"Accurate sizing requires high-fidelity Energy Management Systems (EMS) to model bidding strategies and operations in electricity markets…"

- The RMS errors noted in the abstract are not especially meaningful when given as numerical values (to the reader who doesn't yet know what are the scales of the metrics being evaluated). It would be more useful to give these as a percentage or to add the relevant context.

Answer:
Removed RMSE of hourly data and added Normalized RMSE (NRMSE) of yearly revenues in percentages. Added ranges for RMSE of profitability index.

Changes in paper:
l.11- 16: "This surrogate achieves a normalized root mean square error of 0.81% in approximating yearly revenues. This method proves effective in accurately evaluating the operation of HPPs across various geographical locations and hence in multiple sizing problems. Furthermore, we utilize the surrogate to evaluate the profitability of several HPP sizes, achieving a root mean square error of 0.010 on the profitability index, with values ranging between -0.13 and 0.18. This demonstrates that the developed surrogate model is suitable for HPP sizing under the given cost and financial assumptions."

- Table 1 certainly motivates that using a high-fidelity EMS can be computationally expensive, but without direct comparisons in your own results it is difficult to assess the relative value of the SM approach.

Answer:
We have now removed this Table and replaced it with text in l. 78-100 where the computational burden of the high-fidelity EMS is detailed. The comparison between the HF EMS and the surrogate is highlighted in Section 5.4 and Section 6 l. 541-546.

Changes in paper:

l-78-100: "The trade-off between computational efficiency and model accuracy presents a significant challenge for the optimal sizing of HPPs. A sizing optimization of an HPP involves maximizing a financial metric by varying the wind power plant rating, battery energy, and power ratings. Calculating that financial metric requires solving an EMS model for each potential HPP configuration. Consequently, HF EMS models offer precise assessments; however, relying solely on them is impractical due to their substantial computational demands. Conversely, using LF EMS models reduces computational time but risks compromising the financial viability of the project due to inaccurate assessments.
To illustrate the computational burden of an HF EMS model, we evaluate the state-of-the-art EMS developed by Zhu et al. (2022) This model requires 1,250 minutes to solve for 25 years of operation (the assumed lifetime) of a given HPP using a single-node High Performance Computing (HPC)

cluster, Sophia (DTU HPC Cluster, 2019), which has 32 physical cores (2 × sixteen-core AMD EPYC 7351) and 128 GB of RAM (4 GB per core, DDR4@2666 MHz). Therefore, even if we need to evaluate only a few sizings for the optimizer to converge, we require a substantial amount of time to reach a solution. For example, evaluating 10 sizings takes 12,500 minutes, or approximately 208 hours. Additionally, in previous work familiar to the authors Leon et al. 2024, a sizing optimization can take up to several hundred iterations to approach optimality. In that study, the authors use a low-fidelity EMS model to evaluate the operation of an HPP over its lifetime in a matter of 15 seconds. The comparison of the optimization time is based on the same computational resources.
Given these computational benefits, HPP sizing optimization often relies on LF EMS models. For example, Leon et al. 2024 propose a methodology for sizing HPPs as a nested optimization problem, using two LF EMS models: a short-term EMS formulated as linear programming and a long-term rule-based EMS. The short-term EMS provides a baseline for daily optimal operations, while the long-term EMS modifies these operations to account for degradation effects and forecast inaccuracies over the plant's lifetime. Similarly, in a study aimed at optimizing the design and layout of a hybrid wind-solar-storage plant, Stanley and King (2022) employs a simple battery dispatch model, where the battery is only discharged to meet minimum power requirements. While using LF EMS models may result in reduced accuracy in revenue estimation, they are widely adopted in HPP sizing due to computational efficiency. Indeed, several review studies underscore the prevalence of LF EMS models in sizing methodologies (Roy et al., 2022; Lian et al., 2019; Thirunavukkarasu et al., 2023)"

l-541-546: "The fast and accurate surrogate allows us to evaluate an HPP's profitability throughout its lifetime with little computational burden. Indeed, the surrogate model is capable of evaluating the NPV/CAPEX for all 50 HPP configurations in Fig. 10 in 25 seconds. In contrast, computing the same evaluations using the high-fidelity model for each HPP configuration, with inputs spanning over a year, would take approximately 39 hours. However, it is important to understand the impact of the surrogate's accuracy on the PI. Figure 10 shows that the surrogate can be reliably used if slight deviations of around 0.010 in the PI are acceptable for the intended business evaluation. In other words, the error on the computed NPV is around 1% of the CAPEX."

- Many abbreviations are defined multiple times (e.g., SM on both lines 113 and 122); please check that all are defined only the first time they are used. (I see PI and HPP re-defined as late as p. 18.)

Answer:
Changes were carried across the paper.

- Dispatch intervals are given as both 15 min (line 126) and 5 min (line 135). I assume from other parts that 5 min is a typo but please clarify if not.

Answer:
Indeed, it was a typo. Thank you for pointing it out.

- There are several 1-sentence paragraphs that interrupt the flow. For example the sentence on line 139 (introducing Figure 1) could easily be combined with the paragraph starting on line 140 (and similar in subsequent instanced).

Answer:
All 1-sentence paragraphs are now combined with their corresponding paragraphs.

- Table 3 clearly indicates many variables and constraints but it would be useful to tie these more explicitly to the computational burden noted as a goal for the proposed surrogate model. Is this table related to the 47-min computation noted on line 148?

Answer:
These indeed refer to the 47-minute computation time. In the text, we explain that each iteration of the MILP and MIQP problem is solved quickly, in less than 0.15 seconds (l. 220). However, many of these optimization problems must be solved sequentially, leading to the 47-minute computation time for one year of input data. The text was slightly modified to make it more explicit that we are referring to the HF EMS on which the surrogate is based.

Changes in paper:
l. 216-224:
"It was observed that for a given HPP configuration, 47 minutes were required to compute the outputs for one year of operation of the HF EMS model. The underlying reason for this is due to the iterative and sequential nature of the framework. For each day, the MILP optimization is solved first, followed by the MIQP for each dispatch interval (e.g., 96 times per day). While each iteration of the MILP and MIQP problems requires a minimal amount of time (less than 0.15 seconds), the frequency of these optimizations is substantial. Moreover, since each time step depends on the previous one, it is necessary to perform the optimization sequentially. Table 3 shows the number of decision variables and constraints required to optimize for inputs spanning over one year. This highlights the substantial computational time required to optimize the sizing of an HPP based on such an operational model."

- (1)-(3) are ratios, not equations as stated. Either give them (short) variable names or omit the equation treatment (you use the ratios as is later in the paper, e.g., line 205)

Answer:
Thank you for noting it. The ratios are included in the text, and the equations were removed.

- I struggled at times to understand which surrogates were being described and analyzed. It would be very helpful to give the four surrogates in Table 5 names (e.g., S1, S2, etc.) and then use these names consistently throughout the rest of the paper (e.g., "…surrogate S1…")

Answer:
Thank you for the suggestion. The surrogates have been named S1-S4, and the text, figures, and tables were modified accordingly.

- Captions in general are quite short and could be more descriptive. As one example, it would be easier to understand Figure 2 if the 2 sentences on lines 210-211 explaining the nomenclature were in the caption instead of the body text.

Answer:
The captions have been changed so that most figures are more descriptive. Additionally, all metrics and variables are now explained before each figure.

- Also in Table 5 I assume that "FFN" is a typo and it should be "FNN"; otherwise, please explain.

Answer:
Indeed, it is a typo.

- It is not clear what would be the desired level of truncation for the principle component matrices Z (line 220); how was this desired level selected?

Answer:
Thank you for pointing that out, I apologize for the oversight. Additional text is now added to explain that the truncation level is such that we have an explained variance of 99%: l. 274-278.

Changes in paper:
l. 274-278: "After applying Singular Value Decomposition (SVD) to both matrices, M_{in} and M_{out}, we extract their principal component matrices and truncate them to the desired level. As a result, we obtain two sets of matrices with different truncation levels, – denoted as r_{in} and r_{out}, respectively. The truncation level is chosen so that the explained variance is 99%; for the definition, see Eq. 4 of Freire and Ulrych (1988). Table 6 presents an overview of the features and samples of each data-processing method for input and output data spanning over a year."

- Line 257 is missing the word "Appendix"

Answer:
Word added.

- Please clarify if the y terms in (8) are for the normalized or actual values in the time series. Line 266 suggests normalized but 269 and 270 discuss true and predicted data without the normalization qualifier. This will also impact the quality of the results as measured by RMSE (i.e., relative to a scale of 0-1 or a much wider scale from the original data).

Answer:
Note that Eq. (8) is now Eq. (5).
The y-terms refer to the normalized values. The variables within the RMSE' equation (5) are now modified for clarity. Additionally, the figures now show explicitly when the normalized variables are used.

- Why is the text below (9) only appearing in a subset of the page width?

Answer:
It is now integrated into a paragraph.

- Line 300 explains PI in words, but the equation doesn't appear until approximately a half page later; could be more streamlined to just have the equation in the paragraph where it is introduced.

Answer:
Thank you for the suggestion. We have included the equation for the PI in the paragraph.

Changes in Paper:
l. 338-337: "A more meaningful measure is the Profitability Index (PI), calculated as *NPV/CAPEX*."

- I recommend avoiding use of longer, non-standard words as "symbols" in equations, e.g., "Profit_y" in CF_y on line 319, as this makes the equations harder to read. (I understand that CAPEX and OPEX are often used as such in equations in wind energy related publications.)

Answer:
We have changed some variables according to the comment.

- Line 341: I assume it should be (y_b(i_b)) (subscripts) as in the equation.

Answer:
Indeed, thank you for pointing it out.

- Lines 354-355: these variables have been previously defined

Answer:
This is now corrected.

- Lines 362-363: I don't know what "This tool is based on re-analyzes…" means. Re-analyzed?

Answer:
There was a typo; it is now changed to "meteorological reanalysis data."

- Please ensure adequate font size in all figures (especially Figure 4)

  Answer: this has been modified.

- Typo in Figure 4b caption (should be Normalized prices)

Answer: Figure 4 is now removed.

- Section 4.1.3: are 250 or 200 HPP configurations studied? The end of p. 16 says both.

Answer:
The paragraph of this section is now modified for clarity: there are a total of 250 HPP configurations used, 200 for training and 50 for validation. All configurations are unique.

Changes in paper:
l.376-378: "To ensure an equal distribution of all variables across the entire parameter space, the Latin Hypercube Sampling method, by Jin et al. (2005), is used to randomly select 250 sizing configurations, of which 200 HPP (80%) are used to train the regressor and 50 HPP (20%) are used to evaluate the accuracy of the surrogate, as detailed in Section 2.2.2."

- Figure 5(b) is an interesting way to visualize the different probability distributions but needs explanation since it is non-standard. Also, the y-axis needs units (MW?)

Answer:
An additional explanation is now included to explain the plot: l. 413-426. As the y-axis has normalized wind power generation, it is unitless.

Changes in paper:
l.415-418: "The wind generation distribution across all locations is available in Fig. 4. This violin plot illustrates the distribution of normalized wind power generation across five different locations (X, A, B, C, and D). Each half-violin represents the density of wind power measurements for a location, showing where values are most concentrated. The symmetrical nature of each violin plot, with mirrored halves for each location, is a standard feature of violin plots that allows for a clearer visualization of the data distribution, where each half represents the same distribution of wind power measurements. The width of each violin indicates the density: wider sections reflect more frequent occurrences of those power levels, while narrower sections suggest less common values. The plot uses a logarithmic scale on the y-axis, making it possible to visualize variations in power generation across a broad range, from very low to high outputs. Inside each violin, the black bar marks the interquartile range, while the white dot represents the median of the wind power measurements for that location. This combination allows for a clear comparison of both the range and central tendencies of wind power output across different sites. For example, a location with a narrower and higher median distribution might experience more consistent and higher wind power generation (i.e., location X), while one with a broader distribution and lower median could have more variability (i.e., location C). Locations A, B, and D share similar distributions where the shape of these distributions suggests that low power output is more common, with occasional rises to higher values."

- Please ensure that all results in Section 5 (figures, tables, and text) are clear about which surrogate model has been used (referring to the suggestion to give them names in Table 5)

Answer:
The results in this section now refer to the best-performing surrogate, model S4. This has been clarified in the text. The comparison of the performance of all surrogate models is now moved to Appendix A.

- For Figure 6 and 7 (and related discussion), I refer back to my question about whether the RMSE is based on the normalized data to help the reader evaluate the quality of the method.

Answer:
Note that Figures 6 and 7 are now Figures A1 and 5.
For both figures we use normalized data. For Figure 5, we now explicitly mention it in the text and on the figure by using the normalized variables as the x-axis labels. For figure A1 we mention in the text leading up to the figure that we use the normalized data.

- For Figure 8, instead of noting "MegaWatts" in the caption it would be better to include "(MW)" in each of the y-axis labels

Answer:
This has changed.

- On line 435 and related discussion you mention the “density” of the data points but the colorbar on Figure 9(a) has units of “count”. I understand that these are related but more precise language would be more clear.

Answer:
This has been clarified in the text: l. 458-459.

Changes in paper
“The hexagonal bins group nearby points (denoted as count in Fig. 7(a)) and show the density of data points within each bin.”

- Line 477: please name the surrogate used instead of “the selected surrogate” here, as well

Answer:
This has been modified as suggested.

- Line 515: “…all HPP configurations are not profitable…” has a different meaning than “…not all HPP configurations are profitable.” I think you mean the latter and should therefore revise accordingly.

Answer:
This has been modified according to the suggestion. Thank you.

- Typos and grammar to change:

-line 17: “wind power plants are” (should be plural)
-line 20 appears to be missing a space between “.This”
-line 42: “accurate forecasting can mitigate these penalties” should be proceeded by ; (not a comma) or a standalone sentence
-Table 1: “Iterations” should be plural
-line 90: the sentence starting “Two of which” is incomplete
…and so on. I recommend a close re-reading as part of the revision process to address these and similar errors throughout.
Answer:
Several of these mistakes have been modified after a closer re-reading.

- Furthermore, I believe the citation format is not aligned with WES standards (Author, Year) in most cases except where the author’s name is part of the sentence (e.g., “Author (year) showed that…”).

Answer:
Several re-readings and editing have been carried out to correct for theses mistakes.