THE IMPACT OF LOW-RESOLUTION INFLOW DATA ON ENERGY SYSTEM OPTIMIZATION MODELS

***Felix C. A. AUER[1,2], Diego A. TEJADA-ARANGO[3,4], Sonja WOGRIN[1,2]**

Introduction and Motivation

The transition of energy systems towards renewable energy sources requires a detailed representation of the intricacies of each renewable technology. One major difference between most renewable energy sources and fossil-based technologies is their inherent intermittency and limited dispatchability. To achieve a 100% renewable energy system with photovoltaic (PV) and wind generators, storage technologies are required to counterbalance this intermittency and still have a reliable system. Hydropower, on the other hand, offers some flexibility to shift energy output throughout the day (through hydropeaking for run-of-river plants) or even between seasons (for (pumped-)hydro-storage plants or large hydro-reservoirs). Therefore, hydropower is a valuable asset, especially for countries such as Austria, Norway, or Brazil, where hydropower plays a significant role in power production.

Previous work has shown the impact of different methods to model the physical and regulatory constraints of hydropower generators on results of Energy System Optimization Models (e.g., [1], [2]). Nonetheless, acquiring accurate inflows as data input for such models remains challenging due to limited data availability and computationally expensive weather simulations. Typically, only monthly or even yearly aggregated data is publicly available. In this work, we focus on the hidden model biases when assuming aggregated, constant inflows compared to using time-variant, hourly inflow data, motivating the importance of detailed time-series data, which is already the standard for wind and PV.

Experimental Setup

The experiments are conducted using the established NREL-118 bus test system [3], which has a network of 186 transmission lines split into 3 zones and 41 hydropower plants, in addition to other energy sources such as thermal power plants, PV and wind generators. We use the Low-carbon Expansion Generation Optimization (LEGO) model [4] to optimize the given system, both in terms of generation expansion and operation with a DC optimal power flow. To identify differences in model decisions more easily, the original input data is adjusted by increasing the demand by 30% and the production capacity of renewables (hydropower inflow, PV and wind) by 50%; however, the fundamental results remain consistent even if the scaling is not applied.

Within the test system, all thermal, PV and wind generators are defined as investable assets, whereas hydropower is treated as existing infrastructure. Regarding the input data, a benchmark result is determined based on the original data provided, where each hydropower plant has a time-variant production capability in hourly resolution throughout the year. This result is then compared to an instance where hydropower generation is averaged over the entire year.

Results

The optimization results obtained are of course dependent on the individual case, but for the given system we observe an objective function value that is 4% smaller when using time-variant inflow data compared to using constant data (1636 M€ vs. 1702 M€, including cost for investment decisions and operation). Looking more closely at individual investment decisions reveals even greater disparities (see Figure 1 for details). Especially for investments in renewables, an increased investment of up to almost

[*] Young Author
[1] Institute of Electricity Economics and Energy Innovation, Graz University of Technology, Inffeldgasse 18, 8010 Graz, Austria, +43 316 873 - 7913, {felix.auer, wogrin}@tugraz.at, https://www.iee.tugraz.at/
[2] Research Center ENERGETIC, Graz University of Technology, Rechbauerstraße 12, 8010 Graz, Austria
[3] Energy & Materials Transition Unit, Netherlands Organisation for Applied Scientific Research (TNO), Anna van Buerenplein 1, 2595 DA Den Haag, The Netherlands, diego.tejadaarango@tno.nl
[4] Instituto de Investigación Tecnológica, Escuela Técnica Superior de Ingeniería, Universidad Pontificia Comillas, Calle del Rey Francisco 4, 28008 Madrid, Spain

400% can be observed. Even for zone 1, the area with the largest production capacity, the investment in solar generators is 16% higher. This suggests that the model manages some variability via its thermal generators and their ramping constraints, though only to a limited extent. When the hydropower plants are time-variant, the ramping capabilities of the thermal generators are required to compensate for their fluctuations. Conversely, if constant inflow data is supplied, the model invests more into solar production since it seems that the system can handle more variability.

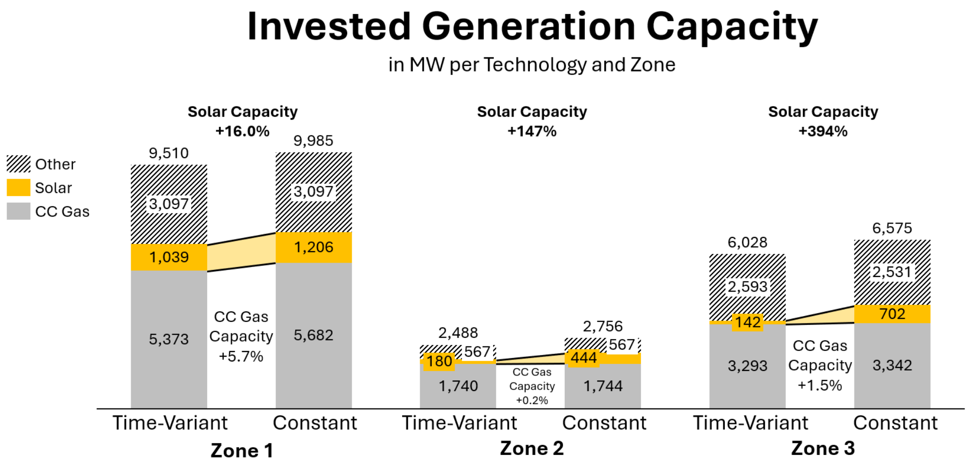

Figure 1: Comparison of invested generation capacity in MW per technology and zone with time-variant or constant inflow data. Technologies with limited differences or investments below 100 MW are in category "Other".

Conclusion and Future Work

We have experimentally shown the differences in model results when using more realistic time-variant, hourly inflow data compared to frequently available constant data averaged over individual months or even full years. The results demonstrate the need for detailed inflow time-series, as it can otherwise lead to a distortion of investments and potentially to an unreliable system.

Potential future research directions are:

- Further examining the effects when using different levels of detail of input data.
- Investigating the impact of coherent time-series of multiple renewable energy sources (e.g., hydropower, PV and wind) belonging to the same weather year compared to non-coherent time-series, where each energy source is coherent only within its own domain.
- Providing a software tool that allows to generate time- and space-coherent time-series for all renewables based on weather realizations.

Acknowledgement

This work is part of the project iKlimEt (FO999910627), which has received funding in the framework "Energieforschung", a research and technology program of the "Klima- und Energiefonds" of Austria.

FFG
Forschung wirkt.

References

[1] A. Nerger, A. C. P. Martins, E. M. Soler, A. R. Balbo, and L. Nepomuceno, "A nonlinear multi-period hydrothermal optimal power flow model for hydropower systems," *International Journal of Electrical Power & Energy Systems*, vol. 155, p. 109585, Jan. 2024, doi: 10.1016/j.ijepes.2023.109585.

[2] E. Blom and L. Söder, "Accurate model reduction of large hydropower systems with associated adaptive inflow," *Renewable Energy*, vol. 200, pp. 1059–1067, Nov. 2022, doi: 10.1016/j.renene.2022.09.060.

[3] I. Peña, C. B. Martinez-Anido, and B.-M. Hodge, "An Extended IEEE 118-Bus Test System With High Renewable Penetration," *IEEE Transactions on Power Systems*, vol. 33, no. 1, pp. 281–289, Jan. 2018, doi: 10.1109/TPWRS.2017.2695963.

[4] S. Wogrin, D. A. Tejada-Arango, R. Gaugl, T. Klatzer, and U. Bachhiesl, "LEGO: The open-source Low-carbon Expansion Generation Optimization model," *SoftwareX*, vol. 19, p. 101141, July 2022, doi: 10.1016/j.softx.2022.101141.