HOW WELL DO WE UNDERSTAND OUR POWER SYSTEM MODELS? - A HANDS ON EXEMPLARY ANALYSIS OF THE TIME RESOLUTION

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Overview

The high ratification rate of the Paris Agreement (UNTC, 2018) indicates a global interest in carbon mitigation strategies and actions. As every change also bears risks, policy-makers need to identify feasible and sustainable decarbonisation paths which will strengthen the individual economies and increase welfare. Due to the pending structural changes, bottom-up energy system models play a major role in the decision making process. Since models will always depict a simplified vision of reality, it is essential to understand the underlying error mechanisms which influence the results. Although recent studies show (e.g. Deane et al., 2014) that the influence on system costs of sub-hourly modelling may be neglectable, no sufficient guideline or error estimation exists to the knowledge of the authors. Keeping in mind, that most scenarios for our future energy system contain significant amount of fluctuating renewable energy sources (e.g. IEA, 2018), we should at least be able to determine the potential error for the different parts of the model results.

Methods

This paper investigates the influence of time resolution on model results. For this analysis, the European Electricity Market Model E2M2 (Sun, 2013) has been used. It has its focus on the power system and is able to depict the electricity side of sector coupling technologies. E2M2 typically optimizes unit commitment and LP relaxised investment for an hourly resolved year for Europe. However, in order to grasp the error mechansims, simplification regarding the regional scope and technological granularity have been necessary. With regard to the error mechanism analysis, the model has been extended with the capability to comprise a variable time resolution (Savvidis and Hufendiek, 2018). Typically, modelers use such methods to reduce the size of the optimization problem without significantly influencing the results. However, we want to use this approach to specifically provoke and analyse the influences of non-optimal chosen time resolution. Advantages over the classical approach of globally changing the time resolutions arises in the ability to isolate the effect of non-optimal time resolution at one (or multiple) specific time steps.

Target of this analysis is the error mechanism which influences the unit commitment at time steps, where the residual load passes the value 0. This effect has been described in (Savvidis and Hufendiek 2018) as the zero crossing effect. It arises from the discontinuous nature of model behaviour at such points in time. As long as the residual load is positive, the model needs to generate electricity. At negative residual loads, surplus energy is available for filling storages. When time is aggregated to a lower resolution at such points, information of this discontinuity is lost, as shown in Figure 1. For the analysis at hand, we will use a quarter hourly resolved variable time step model, where zero crossing time steps are aggregated to an hourly resolution. This allows the exact analysis of the zero crossing error at hourly resolved models (benchmarked against a quarter hourly resolved model). Quarter hourly resolved data from the German TSO “50 Hertz” has been used. Installed capacity of existing storage units has been scaled by a factor of 4 and RES capacities are chosen to depict Germanys 2030 targets.

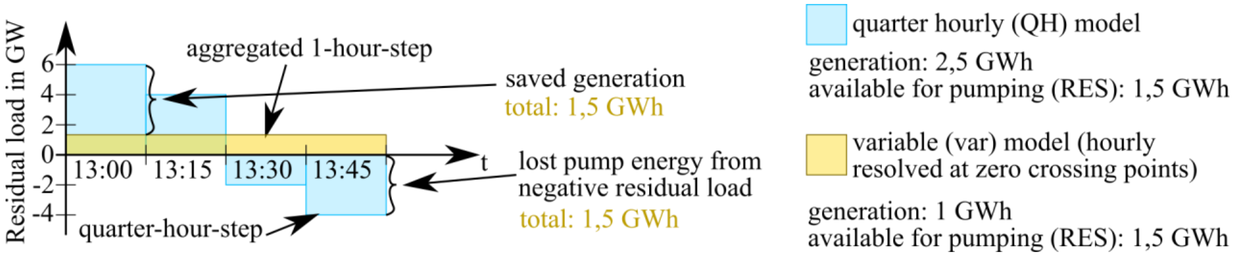

Figure 1: The zero crossing effect. An overview of lost and saved amounts of energy.

Results

Figure 2 shows the preliminary results of the zero crossing error analysis. On the left, the 2 columns describe the theoretical (potential) error which can be calculated in advance with the information in Figure 1. It represents the potentially, through time aggregation not available, energy (from RES) for storing and the saved generation from dispatchable plants. Due to the nature of the aggregation process, the potential lost pumped energy and the potential saved generation comprise the same amount of energy. If the lost energy and the saved energy is summed up, no energy is lost or gained. Due to storage constraints (e.g. maximum filling level) not all of the potential would be used in the models. A quarter hourly resolved model (QH) has been also run to identify how much of the this energy would be used (actual lost pumped energy). The hourly resolved variable model, which cannot use the lost pumped energy, will replace it with surplus generation from dispatchable units. This may be through direct replacement of the dispatch or by charging of storages through other units. Note, that the storage losses of the direct replacement will not occur! This leads to an imbalance determined by the avoided storage losses (and the changes in curtailment). Although the potentials are equally high, the different treatment of energy on the side of the storages leads to a reduced electricity production of dispatchable units.

The lower right part of Figure 2 shows this difference. In this case, the error equals about 3 GWh of generation, which would be missing in an hourly model due to the zero crossing effect. If a quarter-hourly model run is not possible, a worst case assumption of about 14 GWh (potentially saved generation) is applicable. This estimation enables modelers to determine an error margin for e.g. deviation in fuel use, CO2 emissions, storage full-load-hours and system costs.

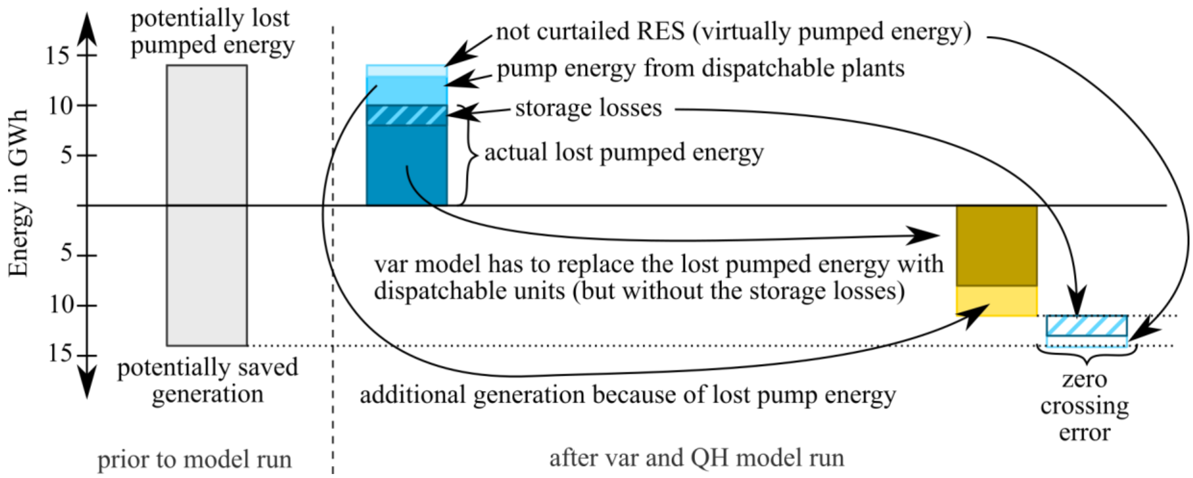

Figure 2: The error mechanism at zero crossing time steps. Energy balances betweem a non-optimal variable resolved model and an optimal quarter-hourly resolved model.

Conclusions

Even though the preliminary results have shown that the total influence of the analysed error might be neglectable for most use cases of the model results, it should be best practice that modelers state the potential margins of error for the chosen time resolution. This applies especially when time resolution is chosen to be other than hourly or sub-hourly. But also for the range of future scenarios, where variability of the residual load might be much higher than in the analysed case, stating the error potential of the chosen time resolution increases transparency, and hence, the trustworthiness of the results. The authors pledge, that modelers should intensively work on identifying the error mechansims in their models. Providing indicators of potential model errors significantly helps in the correct interpretation of the model results.

References

1. Sun, N. (2013): Modellgestützte Untersuchung des Elektrizitätsmarktes: Kraftwerkseinsatzplanung und –investitionen. Universität Stuttgart

2. United Nations Treaty Collection (UNTC) (2018): Chapter XXVII 7.d. Paris Agreement. Status as at: 16-12-2018 05:15:51 EDT. https://treaties.un.org/Pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-7-d&chapter=27&clang=_en (last accessed: 16.12.2018)

3. Deane, J. P.; Drayton, G.; Gallachóir (2014): The impact of sub-hourly modelling in power systems with significant levels or renewable generation. Applied Energy, vol. 113, pp. 152-158.

4. International Energy Agency (IEA) (2018): World Energy Outlook 2018.

5. Savvidis, G.; Hufendiek, K. (2018): Variable time resolution in LP electricity market and investment models. In: 2018 15th Internation Conference on the European Energy Market (EEM), Lodz, Poland.