THE ROLE OF CURTAILMENT IN DEALING WITH THE VARIABILITY OF RENEWABLES

Erik Delarue, KU Leuven - Energy Institute, TME Branch, +32 16 322511, erik.delarue@mech.kuleuven.be

Overview

Worldwide, electricity generation systems are undergoing major changes. The share of renewable energy sources (RES) is growing significantly, mainly driven by growing concerns on global warming and for reasons of strategic energy security. These RES, however, often have an intermittent profile. Their output is predictable only to a limited extent, and it is variable, not or only in a limited way dispatchable (e.g., they might be curtailed, reducing their output). The impact of these RES on the system operation is twofold: first, they reduce the residual load (i.e., the original load with RES generation subtracted). Second, also more flexibility is required to deal with the higher variability and unpredictability of the residual load. Hence, these effects need to be carefully accounted for.

Given the relatively low load factor of wind (20-40%) and solar PV (10-20%), high levels of installed capacities have to be put in place to yield a significant share of overall RES electricity generation over time. At high capacities, RES might generate near full capacity at certain moments in time, thereby potentially exceeding original electricity demand. After exploiting flexibility instruments such as storage or demand response, curtailment of RES might be required. Also in terms of system stability, Transmission System Operators (TSOs) typically specify a certain minimum threshold of conventional ‘synchronous’ capacity to be online, to provide kinetic inertia to the system (Mc Garrigle et al., 2013; IEA, 2014). This might further limit the amount of RES that can be absorbed by the system. Curtailment of RES might also actually yield system benefits, before such limits are reached. It might help to limit net-load ramp rates, or can avoid having to shut down a large conventional plant and having to start it up a few hours later again (Klinge Jacobsen and Schröder, 2012).

The focus of this paper is on the role of RES curtailment, considering wind and solar PV. Minimum curtailment levels (from a technical perspective) and “optimal” curtailment levels (from a system wide economic perspective) are being assessed. System benefits as function of the share of possible curtailment levels (technical and market-wise) are identified, thereby extending findings available in the existing literature.

Methods

A detailed electricity market model is set up and employed. Focus is on a set of Western European countries. The electricity generation system is taken as given, together with an original load profile and a certain generation profile from RES. The objective to be minimized is the total generation cost, which is equal to the sum of fuel costs and startup costs over all conventional power plants (i.e., all plants excluding intermittent RES) and all time periods (in this case hourly time steps). A stepwise fuel cost function, minimum operating point and minimum up and down times are being considered for conventional generators. Curtailment of RES is gradually allowed. The model provides as output generation levels on an hourly and individual power plants resolution, and costs.

The model is set up as Mixed Integer Linear Programming (MILP) model in GAMS 24.1.3 and solved with Cplex 12.3. Specific focus in the implementation is put on efficient computation. As the computational complexity for MILP increases exponentially with the problem size, it is difficult to solve large instances as single optimization. Hence, the model is solved for weekly blocks (168 h), with each time one week overlap, to ensure feasibility (i.e., an optimization basically covers two weeks, after which only the results of the first week are preserved).

Results

In this first (preliminary) stage, the developed methodology is applied to a case study for the Belgian system. Data is in general based on available data from the Belgian TSO Elia (2014). The conventional electricity generation system is (methodologically) represented by 49 power plants. The share of RES is gradually increased in this system. The impact of curtailment is analyzed.

Some preliminary results are presented in Figure 1 below. The importance of curtailment is indicated by the increasing level as function of RES penetration, reaching already significant amounts around 20% of RES contribution (panel b). In this case, no restriction is set on the curtailment that would be allowed.

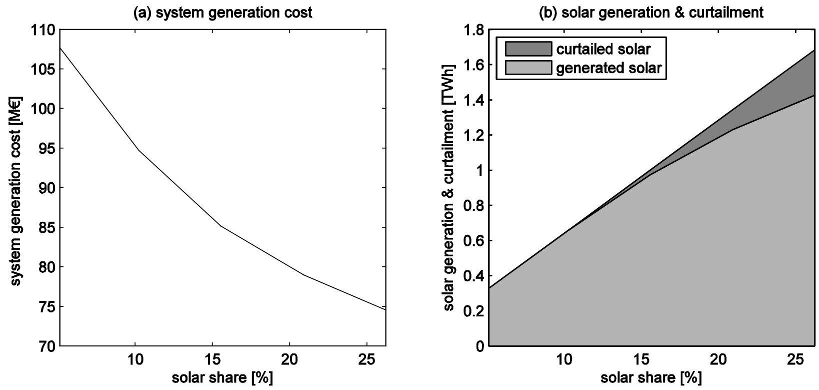

Figure 1. (a) system cost and (b) solar PV generation and curtailment, both as function of share of solar PV.

Further simulations will be executed, focusing on the impact of the share of allowed curtailment. Technical limits might hamper curtailment up to the optimal level. For example, solar PV panels at domestic level are typically not equipped with real time metering nor control devices. Also economic incentives might be lacking to achieve optimal curtailment. Subsidies such as feed-in tariffs might still provide incentives for RES to generate, even when wholesale price turn negative (and hence, when curtailment would be beneficial on a system level). Clearly, adequate market design and subsidy mechanisms are to be defined and set up to provide the right incentives to RES generators.

In the full paper, the impact of the fraction of possible/allowed curtailment will be assessed. The relationship between the level of possible/allowed curtailment and the overall system cost will be defined. Also a wider geographic area will be considered (i.e., Western Europe). This way, the benefits of curtailment can be assessed.

Conclusions

Results are still preliminary, but the following trends already emerge.

Existing electricity generation systems (with RES being superimposed) are able to absorb a significant share of RES. However, curtailment of RES seems required to achieve optimal system operation, and starts playing a role as from an overall RES contribution of about 15%. The impact of curtailment feasibility on overall system cost will be further assessed.

To allow for curtailment, this must be feasible/achievable, both in technical terms as well as in a market context. Technically, wind power generally can be controlled and regulated downwards. For solar PV, this is most often not directly the case in current settings (domestic role out, no real time metering or control). Regarding the market setting, adequate incentives are required to trigger curtailment. A full assessment of these issues will be provided in the paper.

References

Elia (2014). Belgian transmission System Operator. http://www.elia.be/en/grid-data

IEA. (2014). The Power of Transformation - Wind, Sun and the Economics of Flexible Power Systems. OECD Publishing, Paris.

Klinge Jacobsen, H., & Schröder, S. T. (2012). Curtailment of renewable generation: Economic optimality and incentives. Energy Policy, 49, 663-675.

Mc Garrigle, E. V., Deane, J. P., & Leahy, P. G. (2013). How much wind energy will be curtailed on the 2020 Irish power system?. Renewable Energy, 55, 544-553.