MODEL-BASED ASSESSMENT OF CONCENTRATED SOLAR POWER IN SPAIN: A CASE STUDY ANALYSIS

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Overview

The use of solar radiation for electricity generation has been dominated by Photovoltaics (PV) over the last decade. Compared to PV, Concentrated Solar Power (CSP) has higher costs and has been less implemented within Europe as well as at global scale. In January 2019, 10 GW capacity of CSP projects around the world were operational, under construction, or under development. 2.4 GW of these projects are located in Europe, with Spain being the dominant market leader having 2.3 GW of installed capacity (SolarPACES, 2017).

Nevertheless, CSP plants offer complementary features to PV generation. In combination with thermal storage, they allow for a variety of applications due to the dispatchibility of their generation. CSP plants can operate as baseload plants and offset conventional power plants. The usage of a thermal storage system can help to increase the capacity factor of the CSP plant. At the same time, the increased dispatchability barely raises the levelised cost of electricity (LCOE) compared to a plant without a storage system (Lilliestam et al., 2018).

Within this paper, we analyse model-wise the interplay of distinct CSP technology concepts with thermal storage units, here exemplified for the case of Spain and including different variations in storage size, solar multiple, natural gas and CO2 price, and shares of wind and solar PV in the electricity generation.

This model-based assessment of CSP in Spain is conducted as part of the Horizon 2020 project MUSTEC funded by the European Commission (MUSTEC, 2018).

Methods

The analysis is based on a detailed techno-economic assessment of different CSP technology configurations including the complementary thermal storage facilities. Characteristics which are of particular interest here are the capacity of the power plant and of thermal storage as well as operational modes of the power plant (baseload vs. peaker, back-up capacity in combination with PV, etc.).

Based on the techno-economic classification, distinct model-based assessments are conducted subsequently. The different technology concepts are modelled using the energy systems model Balmorel (The Balmorel Open Source Project, 2019). Balmorel is an open-source, partial equilibrium model for analysing the electricity and combined heat and power sectors. It is a deterministic model that optimises social welfare considering energy demands along with process-specific constraints. We conduct the simulation in high time resolution analysing the resulting hourly electricity prices.

The analysis is split into two parts: Two case studies serve to shed light on (future) prospects of CSP as either system contributor (case study 1) or to act as generator in accordance with profiling needs (case study 2). A sound data base including all features of the different technology concepts is used in order to evaluate the different implications of the CSP configurations incorporated in the model. This enables a sound comparison of different CSP configurations (for example the size of the complementary storage unit). Since the modelling exercise is done at case study level, the analysis demonstrates the advantages and disadvantages of the different technology concepts under given assumptions and framework conditions.

Since Spain is the global leader in terms of CSP installations, the focus of our model exercise is this country. However, a detailed reflection of the electricity system of the neighbouring countries is ensured. The analysis also covers Portugal and France including exports and imports between the national power systems. This approach enables a broader system view on the integration of the assessed CSP concepts into the local and regional power markets.

Results and conclusions

The model-based analysis allows statements about the conditions under which different CSP technologies can be useful, beneficial or necessary in the current and in a future market design. A focus of the analysis here is how the market value of the produced electricity, as well as the overall economic viability, may change in dependence of the underlying CSP technology concept, including the corresponding storage unit. Figure 1 shows the market values and average annual electricity prices of the different sensitivity analyses of case study 1 – CSP as system contributor.

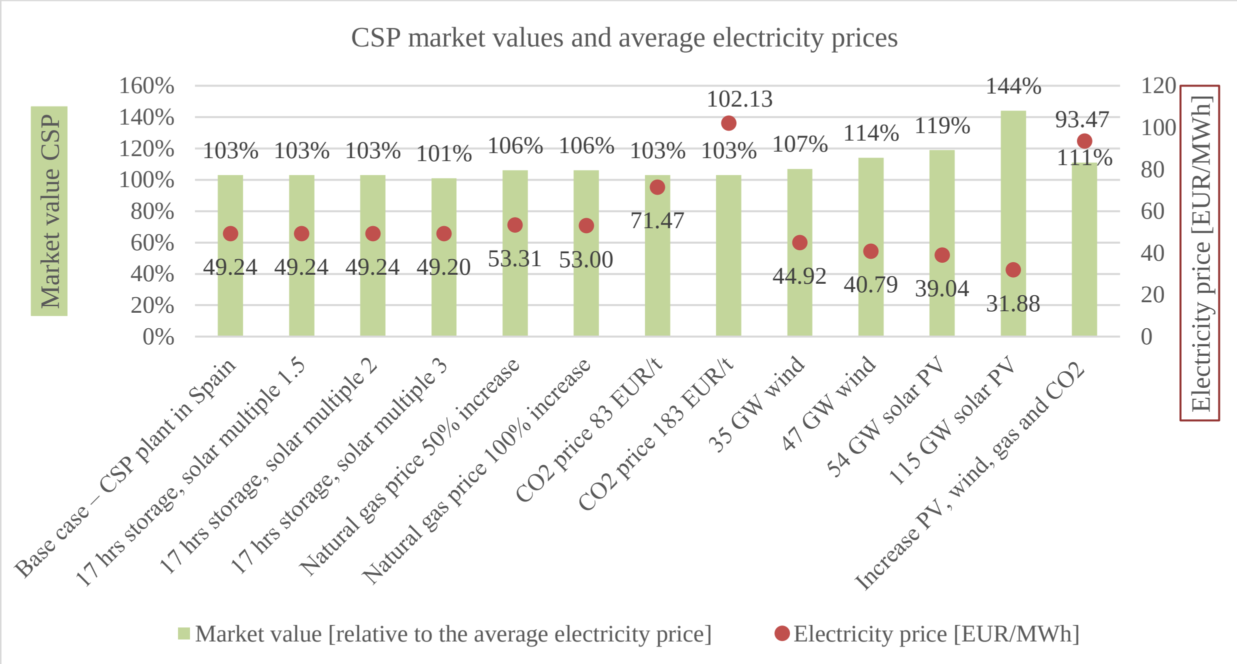

Figure 1: Results of case study 1 – CSP as system contributor in Spain

The resulting market values show how different operational modes of CSP plants and thermal storage facilities can affect the overall economic viability. Systems with a high share of non-dispatchable fluctuating renewables lead to the highest relative market values for CSP (up to 144%): wind has a strong impact, but CSP is most profitable in systems with a high solar PV share. In this setting, average electricity prices are decreasing and CSP is able to shift its electricity generation to times of low PV and wind infeed, and, therefore, higher price levels. However, average electricity prices are the lowest in these sensitivity analyses. This fact also lowers overall revenues.

In contrast to above, in a market setting where in parallel to increased shares of PV and wind also CO2 and natural gas prices are rising, a high market value of CSP (up to 111%) and high average electricity prices lead to high revenue levels for CSP. In a possible future electricity system representing these features, CSP could play out its main operational advantages – dispatchable, renewable, and CO2-free generation of electricity.

References

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