ENCOURAGING HYDRO-SOLAR COMPLEMENTARITY IN THE SWISS ELECTRICITY MARKET

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Overview

Hydropower is not only a renewable and sustainable energy source, but also a flexible technology whose storage capacity improves grid stability and supports the deployment of other intermittent renewable energy sources, such as wind and solar power (Ardizzon, Cavazzini, and Pavesi 2014). This has recently led to a renewed commercial and technical interest in pumped-storage power plants (PSP). These plants participate in two markets: balancing the grid in the ancillary services market and profiting from arbitrage opportunities in the wholesale market. In the latter, these plants operate as a generator when price is high and as a pump when price is low. Thus, the profitability of PSP depends on the price volatility and the cycle performance (ratio between energy produced and energy consumed, 75% to 80%) (Ursat, Jacquet-Francillon, and Rafaï 2012).

Most work concerning PSP is focused on the complementarity between such systems and intermittent renewable energy sources, in particular wind energy, whose output is harder to forecast. Although balancing the output from intermittent sources is a major challenge for electricity markets, these models do not capture the additional benefits that PSP could bring to the system in terms of costs and security of supply (SoS). PSP allows a more cost-effective use of energy sources: pumping when cheap sources are available (typically at off-peak hours) to substitute for more expensive sources when needed (typically at peak hours). This could lead to significant changes in electricity prices, affecting the consumer and producer surplus (Kanakasabapathy 2013). However, PSP are risky investments due to the high investment costs, long construction delays and lifespan, and the dependency on future price patterns.

We focus on the participation of PSP in the wholesale electricity market. We use a system dynamics based simulation model that allows us to model the investment decisions and the market clearing. In particular, it enables us to simulate the strategic behaviour of PSP: when to pump and when to generate in order to maximize profitability. We calibrate our model for the Swiss market, where, around 60% of production comes from hydropower facilities and more than 30% from nuclear facilities.

Over the past decades, Switzerland has aimed to exploit its hydro potential to become the electricity hub of Europe. This has led to major investments in PSP, whose capacity will more than double by 2020. However, the situation has changed following the government’s decision to decommission all nuclear plants within the next 20 years. This decision, as well as the expiration of long-term contracts allowing cheap off-peak energy imports from France and the increasing share of PV, have a deep impact on the economic feasibility of PSP.

Our aim is thus to assess to which extent PSP are affected by those changes and how to encourage their operation and thus improve their profitability. We propose five payment-scenarios to encouraging PSP generation and evaluate their impact on the market’s costs and exchange patterns. We also elaborate on how these plants might contribute to enhancing the SoS of the country. We do not deal explicitly with the participation of PSP in the ancillary services market as grid-leveller, but we do deal with the impact of PV on PSP operation.

Methods

Simulation, System Dynamics

Results

Our simulation model uses a quarterly time step and we consider an average daily demand for each quarter in order to capture both the daily and seasonal aspects of production and demand. These patterns already affect the Swiss market and will be increasingly important in the future, as the role of PV increases. The simulation runs from 2013 to 2050. We assume that demand grows exogenously at 1% per year. Projects currently under construction are included in the model. The model also yields endogenous investments in hydropower. We assume that PSP capacity grows in line with the additional hydro-storage generation capacity. This assumption does not affect our results, as pumping capacity is non-binding in all scenarios.

The main results are as follows:

First, the lack of cheap energy sources endangers the profitability of PSP operation and partly explains why pumping grows less than PSP capacity. Therefore, PSP's utilization rate is expected to decrease.

Second, pumping patterns change over the simulation period. In winter, pumping at off-peak hours (before 6 a.m.) decreases while there is pumping at noon, which is not the case today. This is a consequence of the wider difference between noon and evening prices: price increase at noon is limited due to PV, while evening prices double. In summer, few changes occur at off-peak hours. Little pumping occurs at noon, because of the hourly demand shape and the low intra-day price differences. This result is counterintuitive since one might have expected pumping to occur when PV availability peaks (noon). Nonetheless, the higher availability of PV does lead to a reallocation of production: PV is almost sufficient for meeting demand at noon, allowing hydro-storage to produce more in the evenings. Hence, this results in flatter prices.

Third, we experiment with different payments to encourage PSP generation, and thus pumping. The higher offer of PSP results in a price drop, which decreases the cost of electricity for consumers. If the costs of subsidising such plants is distributed appropriately among both consumers and PSP (whose profits increase significantly), a fairly broader range of payment schemes is beneficial to consumers and producers. However, if the incentive costs are supported solely by the consumers, only a very narrow range of payments is feasible.

Fourth, PSP incentives affect the behaviour and patterns of electricity exchange: imports at peak hours are discouraged by the higher availability of PSP. At the same time, imports are encouraged at off-peak prices for pumping. The overall effect is an increase of net imports but at lower average price but at lower average price.

Conclusions

Our model helps understanding the new challenges that a large(r) output of PV and the absence of nuclear energy pose to PSP profitability. Nuclear energy is mainly replaced by PV and balancing imports. This situation leads to higher intra-day prices differences in winter, which at first sight might benefit PSPP. However, the lack of cheap off-peak load hinders a higher utilisation of PSP. In summer, the highest availability of cheap energy (PV) coincides with peak demand, again hindering the exploitation of PSP. Overall, the lack of cheap sources at off-peak hours negatively affects the operation of PSP.

Our result send a warning message to the market: long-term investments are risky since the market situation can change abruptly. For instance the nuclear phase-out, decided after the Fukushima accident, seriously endangers the profitability of PSP. Such political decisions add uncertainty to the market and change the expectations of investors. The resulting changes in energy-mix not only affect the operation of such plants, but also limit the potential benefits for consumers regarding prices and SoS. The country's SoS is thus threatened since utilities might not be willing to invest in new generation (and pumping) capacity given the risk. Hence, if the regulator is keen to develop PSP, it needs to incentivise them.

An appropriate level of subsidy for PSP generation can bring some benefits: price drops, leading lo lower system costs, and imports at peak-hours are discouraged. However, not all consequences are positive. Net imports increase overall. In addition, flatter prices could have a counterproductive effect on some technologies, e.g. PV and CCGT, whose income could be negatively affected by lower peak prices. Under this situation, they might no longer be able to recover their fixed costs. This highlights the complexity of electricity systems and the challenge faced currently by policy makers, in particular when aiming to improve the SoS of a market. This is why formulating energy policies requires a wider analysis, involving the different aspects of SoS, e.g. price, dependency on imports, capacity adequacy, geopolitical situation. To sum up, incentivising PSPP might result in lower costs but might also have undesirable consequences.

References

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