THE INTERACTION OF A HIGH RENEWABLE ENERGY/LOW CARBON POWER SYSTEM WITH THE GAS SYSTEM THROUGH POWER TO GAS

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Overview

The energy landscape has changed considerably and it is expected that will continue doing so. The share of renewables (RES), especially in the power sector, has increased and the current energy pathways indicate a further increase [1]. However, variability and limited predictability result in new operational challenges for power system operators in maintaining the system balance. Advanced operational techniques will be needed, amongst other options, such as storage, to ensure a safe and reliable operation of the power system [2]. An interesting, possible part of the solution is the "power-to-gas" (PtG) concept [3] that converts excess electricity to hydrogen or methane which can be stored in the gas system. Though the concept of PtG is very interesting, the interaction of the gas and electric systems through PtG need to be studied in detail, which is the subject of this work.

Methods

An operational model for the power sector is set up using linear mixed integer programming, see e.g. [4]. Power generators have the ability to use carbon capture and storage (CCS), depending on the EU ETS price. The model is expanded with a gas spot market with a continuous supply curve, gas flexibility options with associated costs and seasonal gas storage. Furthermore, PtG plants are part of the model, coupled to the gas, electricity and carbon market, see Fig. 1. All conventional power plants are gas-fired (GFPP) and subject to techno-economic operational constraints. The objective of the model is to minimise to total operational costs of providing electricity and gas. Physical gas and electricity networks are not part of the model.

The model has two coupled time scales; a fine scale (15 min) to include short term intermittency of RES, subsequently solved for three days in a rolling horizon approach over a whole year, and a long time scale (5 days) to take into account the value of stored gas over a whole year. The electric and domestic (residential and industrial) gas demands are exogenous to the model. The dimensioning of the PtG plants is evaluated ex-ante through an investment analysis; considering the expected number of operating hours, O&M costs, the value of oxygen and the costs of electric energy, carbon and water.

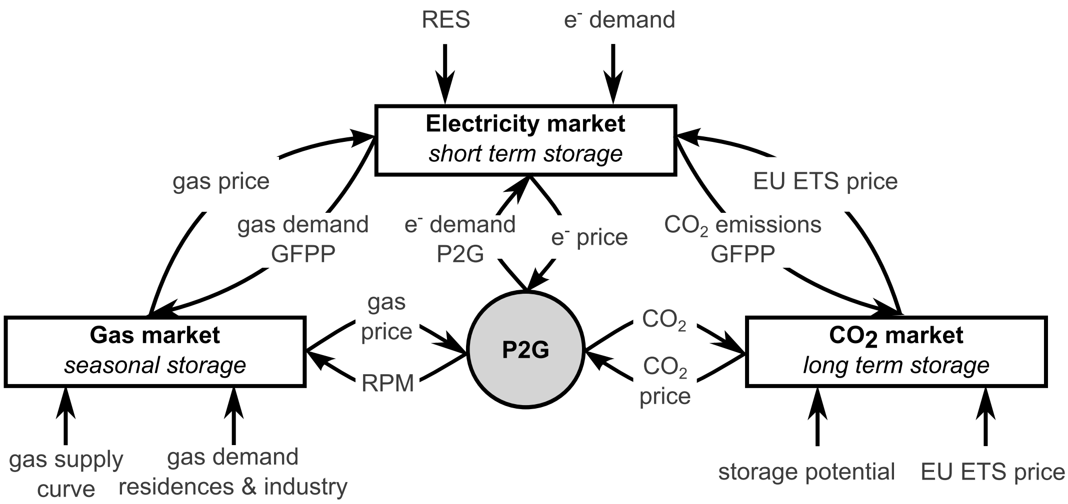

Fig. 1 The electricity, gas and carbon markets are coupled directly. In addition to the traditional coupling between the three markets through the respective price and demand signals, power to gas introduces alternative couplings.

Results

The presented results are obtained from a case with 50% wind and 50% solar (% on electric energy basis). The qualitative effects described below, however, apply more generally as well. The gas prices range from 60 to 75 EUR/MWh and the EU ETS price is assumed 100 EUR/ton. The figures presented below correspond to the same day.

The **electricity** balance is shown in Fig. 2. Wind and solar production are so high that only a limited amount of GFPP production is needed. All excess production (above the Demand line) is converted with PtG or curtailed. It has to be noted that the curtailment does not distinguish between solar and wind.

The **gas** import profile is highly affected by the amount of renewables in the system because all power plants are gas-fired; see Fig. 3. Furthermore, there is also a gas import lowering effect of PtG. For high solar capacities, we often see an inverted gas import peak due to the double effect of (i) no GFPP's are needed during mid-day and (ii) excess solar power is turned into gas through PtG. The remaining gas demand is due to the domestic gas demand, seasonal gas (dis)charging and the use of gas flexibility. We also find that PtG has a downward pressure on the gas prices. In the case where the domestic gas demand is lowered by 75% (not depicted), the gas import profile even reaches zero. The PtG production does not exactly match with the excess production in Fig. 2 because of the used flexibility in the gas network.

Long term **carbon** storage requirements are lowered a lot w.r.t. to the case without renewables because less power has to be generated by GFPP's. When PtG is present, the storage requirements are even lower because carbon is used in the PtG process, see Fig. 4. This lowers the carbon (long term) storage costs, which is an advantage of PtG. This figure also illustrates that carbon storage is not always unidirectional as the PtG plant may use more carbon than captured at certain moments (negative slope of thin black line in Fig. 4). For this particular day depicted, GFPP's are producing electricity only at the beginning and the end of the day, causing the positive slopes of the carbon storage. Without power to gas, the slope is flat during mid-day, as RES covers the electric demand.

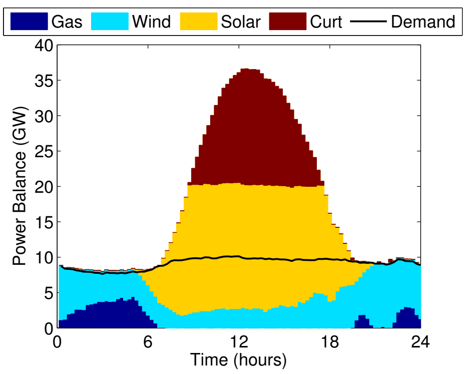

Fig. 2 Electric balance on a day with high solar and wind production. Excess power is curtailed or converted with power to gas.

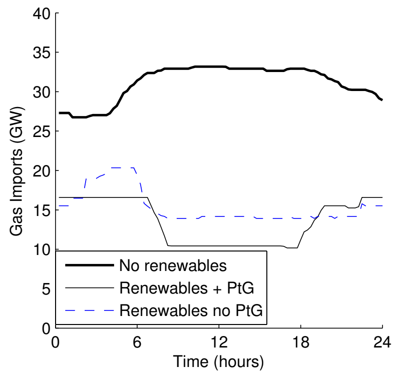

Fig. 2 Gas import profiles. Renewables have the largest impact, but power to gas also lowers the import demand.

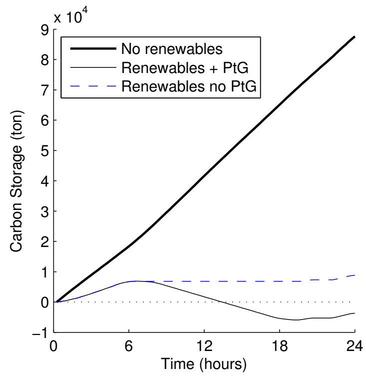

Fig. 4 Carbon storage requirements on a particular day. PtG not only lowers the storage demand but can also inverse the storage flow.

Conclusions

An integrated model has been developed, capable of studying complex interactions of gas, electricity and carbon. A qualitative assessment of the effects with power to gas has been performed. Both the interactions of flows and prices can be studied with the model.

References

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