Remuneration of Flexibility Using Operating Reserve Demand Curves: A Case Study of Belgium

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See footnotes at end of text.

CONTEXT

The recent proliferation of renewable resources has resulted in a decrease of electricity prices and a reduced remuneration of conventional units, which are progressively being retired from operations. This is occurring at the same time that renewable energy integration increases the need for flexibility in operations. Such flexibility can be provided naturally by conventional units. Operating reserve demand curves (ORDC) have been advocated as an economically justified mechanism for pricing flexible capacity in order to compensate conventional units for the loss of energy revenue Hogan (2005), Hogan (2013), and the mechanism has been implemented recently in Texas. The goal in this study is to quantify its impact and assess its implementation possibilities in the European electricity market, with a specific focus on the Belgian electricity market which experienced severe shortage in capacity in late 2014.

PRINCIPLES OF ORDC

The ORDC design is based on the principle that reserve should be valued according to its contribution in reducing the probability of involuntary load curtailment. Scarcity in reserve implies a high probability of involuntary curtailment and hence a high reserve value, and vice versa. On the other hand, the cost of reserve provision is driven by the opportunity cost of keeping capacity in reserve, instead of allocating it for the provision of energy. The ORDC is a *real-time* mechanism that introduces a real-time reserve capacity price and a corresponding adder to the real-time energy price so as to induce an optimal allocation of generation capacity between energy and reserves. The adder is computed as ***(VOLL – MC) · LOLP(R)(VOLL – MC) · LOLP(R)*** , where ***VOLL VOLL*** is the value of lost load, ***MC MC*** is the marginal cost of the marginal unit, and ***LOLP(R)LOLP(R)*** is the loss of load probability given a reserve level of ***R R*** . Although ORDC is a real-time mechanism, given properly functioning forward markets the scarcity signal should back-propagate and signal investment when flexible capacity is short.

The design is appealing for a number of reasons: (i) the adder can be computed ex post, and can therefore be easily integrated to existing operations; (ii) the adder results in more frequent price spikes of lower amplitude, compared to VOLL pricing; (iii) gaming can be mitigated without suppressing scarcity signals; (iv) resources are paid on the basis of their actual performance; (v) in the case of Europe, the mechanism is seen as an alternative to capacity markets that may balkanize European market design and undermine the transition to a common European energy market.

An important question that arises naturally is whether the proposed design can be implemented in the European Union. The ORDC entails a number of assumptions (including co-optimization of energy and reserves in real time) which are not necessarily consistent with present European market design. Before undertaking this more challenging question, the first order of business in the present study is to understand the functioning of the current market. Our study focuses on the Belgian market.

SIMULATING THE BELGIAN MARKET

With the exception of Italy and Spain, there is no day ahead co-optimization of energy and reserves in the EU market design. Reserves and energy are cleared sequentially, with reserve capacity auctions (typically monthly or annual) followed by day-ahead energy market clearing. We solve a unit commitment model with a monthly horizon against real-time demand, as a proxy of the Central Western European market design where reserve auctions are followed by the running of a day-ahead market clearing algorithm (known as EUPHEMIA). We then check whether this proxy fits reality by comparing the predictions of our model to observed outcomes in terms of dispatch by fuel and in terms of market prices.

Figure 1 presents the dispatch of CCGT units (i) using a co-optimized unit commitment (left panel), and (ii) based on the profit maximizing dispatch against observed prices (right panel), which is used as a benchmark for comparison. The centralized unit commitment model is observed to more accurately predict the dispatch of CCGT units, which are the main resources offering operating reserve, and therefore the main drivers for the ORDC adder. This validation procedure seems to verify a 'rational expectation' principle, whereby agents reasonably anticipate the value of the capacity in the energy market and bid accordingly in the reserve market. 'Rational expectation' is a common (but usually untested ex post) assumption in economics. Consequently, even though EUPHEMIA is not a unit commitment model[3], it results in a commitment schedule which is close to the result of a centralized unit commitment model. We thus verify that the unit commitment model provides a reasonable approximation for the use of the machines when capacities are tight. This is a necessary condition for being able to simulate the ORDC add up.

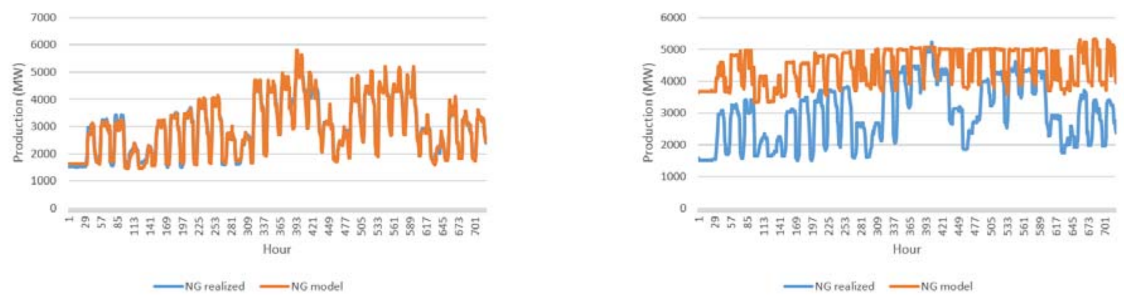

Figure 1: Production of CCGT, in reality (in blue) and according to the model (in orange) for January 2013. The left panel corresponds to a unit commitment model, the right model corresponds to dispatch against realized prices.

Figure 2 addresses the question of whether the unit commitment model can simulate the prices generated by EUPHEMIA. The prices presented in the left panel are based on a model that seeks prices that (i) support continuous bids determined by the unit commitment model; (ii) render block bids found by the unit commitment model in the money; (iii) while minimizing welfare degradation with respect to the unit commitment solution. This results in a bi-level program that seeks prices which minimize deviations from optimal welfare, while being consistent with the solution of the unit commitment model. A benchmark model which sets the price on the basis of the marginal cost of the most expensive slack unit is presented in the right panel. The bi-level model seems to outperform the benchmark. We note that the bi-level model can explain price drops in off-peak hours (due to excessive energy supply stemming from minimum load requirements of units that offer reserve) as well as price spikes in peak load hours (due to the recovery of fixed costs that cannot be recovered in off-peak hours). This further strengthens our confidence in the dispatch schedules determined by the co-optimization unit commitment model.

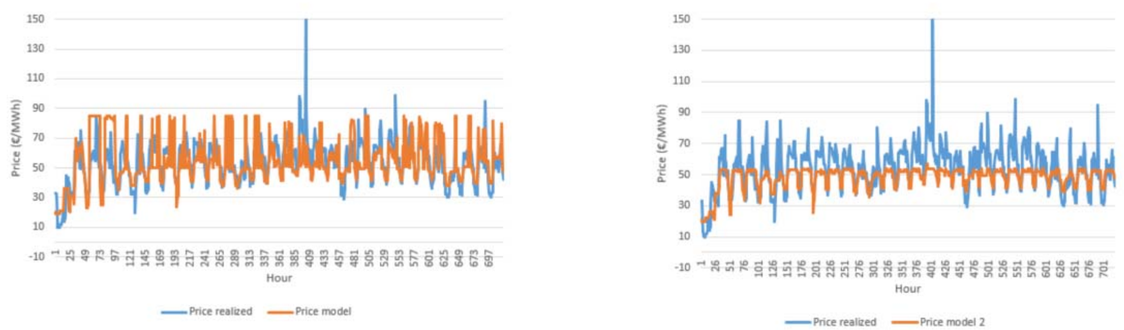

Figure 2: Day-ahead prices in reality (in blue) and according to the model (in orange) for January 2013. The left graph corresponds to the model that account for block bids, the right graph corresponds to the model that ignores block bids.

CASE STUDY

Our study covers the interval from January 2013 until September 2014. The Belgian system consists of 14765 MW of installed capacity. In order to estimate the profits of individual units, we use the historical energy and reserves prices and the output of the unit commitment model in order to estimate revenues and operating costs. We focus specifically on CCGT units, which are the main source of reserve in Belgium. The profits of CCGT units are computed for historical prices as they occurred over the duration of the study, as well as for profits that would have occurred if the ORDC price adder were applied to the energy price. Table 1 presents the profitability of each unit before and after the introduction of price adders. These profits should be compared against the running investment cost of a typical CCGT unit in order to ascertain the economic viability of CCGT resources. The running investment cost of CCGT is estimated at 4.5 €/MWh. Profits that do not exceed 4.5 €/MWh in the table are highlighted in bold font in order to indicate that the given unit cannot recover its investment cost. The profit in the first column is computed as the profit over the entire duration of the study given historically realized prices, normalized by the capacity of each unit and the number of hours in the study period. The profit in the second column is computed in the same way, where prices have been adjusted according to the price adder. The final column represents the extra profit earned by each CCGT unit due to the introduction of the adder, normalized by the total output of each unit.

	Profit (€/MWh) no adder	Profit (€/MWh) with adder	Adder benefit (€/MWh)
CCGT1	3.6	10.6	8.5
CCGT2	1.3	3.6	11.6
CCGT3	1.1	10.0	7.7
CCGT4	3.8	11.1	10.0
CCGT5	0.9	6.4	7.5
CCGT6	3.9	8.3	6.8
CCGT7	1.0	3.2	6.8
CCGT8	1.1	8.0	8.0
CCGT9	2.3	11.1	10.1
CCGT10	1.7	7.4	14.9
CCGT11	1.7	4.3	8.6

Table 1: Profitability of CCGT units before and after adding ORDC price adders, and average adder benefit.

CONCLUSIONS

Three notable conclusions can be drawn from the first two columns of Table 1: (i) CCGT profits, as estimated by the methodology set forth in the present paper, are adequate for covering the *variable* costs of all *existing* CCGT units; (ii) CCGT profits are not sufficient for covering the investment costs of *any* CCGT unit. (iii) Adders, as computed in the study, could potentially render the majority (eight out of eleven) of CCGT units economically viable. These findings are consistent with the ongoing policy debate which centers on the fact that the current EU market design is not sufficient for ensuring the economic viability of flexible resources, although these resources are necessary for supporting the integration of renewable energy resources.

Footnotes

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[3] EUPHEMIA maximizes welfare subject to a constraint on prices (solutions must be supported by an anonymous price system) that is not part of a unit commitment model. This is detrimental to the efficiency of the commitment, but apparently not much in the case of the Central Western European market.

References

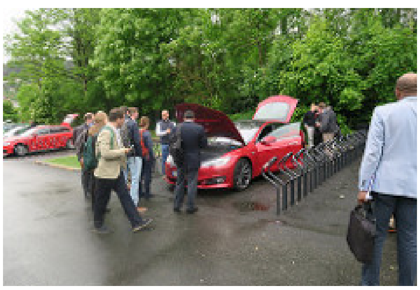
Hogan, W., 2013. "Electricity scarcity pricing through operating reserves". Tech. rep., JFK School of Government, Harvard University.

Hogan, W. W., September 2005. "On an 'energy only' electricity market design for resource adequacy". Tech. rep., Center for Business and Government, JFK School of Government, Harvard University.

Bergen Overview (continued)

Bergen Conference Environmental Considerations

The ride on the electric train was one small symbol of a more general intention of the organizers, i.e. to try to make the conference as environmentally friendly as possible. Other such efforts were to supply conference delegates with a bus card for public transportation between the city centre and the conference venue, the NHH, ca. 7 kilometers each way, and otherwise around in the city and its surroundings; to serve local, short-travelled food for the conference meals; to minimize printing of conference material; and the arranging of an electric car show and parade for delegates to learn about properties of such vehicles, of which Norway has the highest share in the world.



Scenes from the electric car parade

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Scenes from the electric car parade