Demand Participation in Electricity Balancing Markets

Bastian Westbrock[1] Elena Fumagalli[2]

[1]Utrecht University School of Economics

[2]DIG Politecnico di Milano

AIEE Energy Symposium
Nov. 2-4, 2017

Motivation

Winter Package (2016): *Consumers* are active and central players on the energy markets of the future

- Demand participation is encouraged in wholesale electricity markets
- New initiatives to make use of demand flexibility as a resource in ancillary service markets

ENTSO-E (2014): *Balancing services* are "all actions and processes, on all time lines, through which Transmission System Operators (TSOs) ensure to maintain the system frequency within a predefined stability range... "

- Balancing Capacity; Balancing Energy; Imbalance Settlements

Motivation

Italian Regulatory Authority (2016-2017):

- Consultation on the opening of the Italian Ancillary Service Market to demand resources, intermittent renewable energy sources and distributed generation - DCO 298/2016/R/eel
- First opening of the Italian Ancillary Service Market to demand resources, renewable energy sources and storage. Pilot projects. Dispatching Code - Delibera 300/2017/R/eel
- Adoption of prescriptive measures and valuation of potential abuse of market power in light of UE Regulation n. 1227/2011 (REMIT) - Delibera 342/2016/E/eel

Demand participation is technically feasible and meaningful in the light of intermittent energy sources. What does it imply in terms of system costs and benefits?

Outlook

Our paper: From a system perspective, what are the economic implications of procuring balancing energy services from consumers?

Abstracting from speculation, demand participation...

- increases (decreases) the volatility of consumption (production) in the BM
- implements the *ex-post* efficient outcome in the BM (Crampes and Léautier, 2012)
- reduces the cost of maintaining the system balanced
- reduces the risk of a system "crash"

With speculation (Crampes and Léautier, 2015; Just and Weber, 2015), demand participation...

- Same as above, except for the result on the balancing costs now ambiguous

Outline

- Model
- Results without speculation
- Results with speculation
- Conclusions

Model

Market Design:

- A competitive energy market on day $d-1$ (DA)
- A competitive balancing market on day d (BM)

Participants:

- *Wind producers* (only in the DA): no profit motives; total output $Q_d^w(s)$ is distributed according to $F(s) = F(Q_d^w(s))$; s denotes the availability of the wind
- *A number of thermal producers, n^t*: perfectly controllable output Q_d^t; flexible on day d; increasing and convex marginal cost $MC(q_d^t)$
- *A number of consumers, n^c*: perfectly controllable demand Q_d; flexible on day d; decreasing and concave willingness to pay $p(q_d)$

Model

- *Energy Market (DA)*: clears at p_{d-1} so that scheduled demand equals scheduled supply: $Q_{d-1} = Q^t_{d-1} + Q^w_{d-1}$
- *Balancing market (BM)*: two types of balancing services
  - When $s \in S$ s.t. $Q^w_{d-1} > Q^w_d(s)$: the system is negative ($s \in S^n$); the TSO procures $\mu(s) = Q^w_{d-1} - Q^w_d(s) > 0$ of upward balancing energy
  - When $s \in S$ s.t. $Q^w_{d-1} < Q^w_d(s)$: the system is positive ($s \in S^p$); the TSO procures $\mu(s) = Q^w_{d-1} - Q^w_d(s) < 0$ of downward balancing energy

Assumption: independent of whether consumers participate in the BM or not, Q^*_{d-1} is the scheduled output, $\bar{Q}^t < Q^*_{d-1} < \bar{Q}^w$

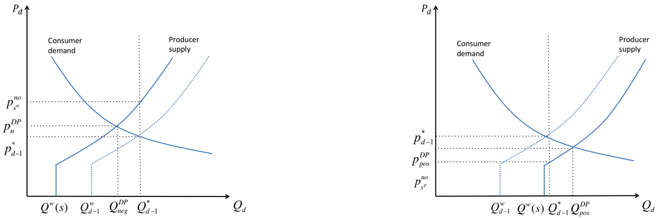

Figure 1: Balancing Market: system is negative (left) positive (right)

Demand participation without speculation

Proposition 1: Demand participation implements the first-best outcome and reduces the cost of maintaining the system balanced

Demand participation without speculation

What if the scheduled output is very large, $Q^*_{d-1} > \bar{Q}^t$, or very small, $Q^*_{d-1} < \bar{Q}^w$?

Proposition 2: Because of the additional adjustment margin, demand participation reduces the risk of a system "crash"

Under demand participation, the total adjustment margin to meet $\mu(s)$ is equal to

$$(Q^t_s - Q^t_{d-1}) + (Q_{d-1} - Q_s)$$

Demand participation with speculation

Without demand participation: Q_{d-1} and Q^t_{d-1} now endogenous

Consumers maximize, w.r.t. q_{d-1}

$$CS = \int_0^{q_{d-1}} p(x)dx - p_{d-1}q_{d-1}$$

Thermal producers maximize, w.r.t. q^t_{d-1} and q^t_s

$$\begin{aligned} \pi &= p_{d-1}\, q^t_{d-1} + \int_{s\in S^n} f(s)\Big[p_s(q^t_s - q^t_{d-1}) - TC\big(q^t_s\big)\Big]ds \\ &- \int_{s\in S^p} f(s)\Big[p_s(q^t_{d-1} - q^t_s) + TC\big(q^t_s\big)\Big]ds \end{aligned}$$

s.t.c. $q^t_s - q^t_{d-1} \geq 0$ if $s \in S^n$, and $q^t_s - q^t_{d-1} \leq 0$ if $s \in S^p$

Demand participation with speculation

With demand participation: Q_{d-1} and Q^t_{d-1} now endogenous

Consumers maximize, w.r.t. q_{d-1} and q_s

$$
\begin{aligned}
CS &= \int_{s\in S^n} f(s)\left[\int_0^{q_s} p(x)dx + p_s(q_{d-1} - q_s)\right]ds \\
&+ \int_{s\in S^p} f(s)\left[\int_0^{q_s} p(x)dx - p_s(q_s - q_{d-1})\right]ds - p_{d-1}q_{d-1}
\end{aligned}
$$

s.t.c. $q_{d-1} - q_s \geq 0$ if $s \in S^n$, and $q_{d-1} - q_s \leq 0$ if $s \in S^p$

Thermal producers maximize π as before

Demand participation with speculation

Equilibrium without demand participation

Q_{d-1} and Q^t_{d-1} are given by:

$$p_{d-1} = p(\frac{Q_{d-1}}{n^c}) = \int_{s \in S} f(s) MC\Big(\frac{Q_{d-1} - Q^w_d(s)}{n^t}\Big) ds$$

In words: consumers pay the expected marginal cost of their scheduled demand plus the balancing energy required to maintain that desired output

Demand participation with speculation

Equilibrium with demand participation

$$\begin{aligned} p_s, Q_s, Q_s^t &: \; p_s = p\left(\frac{Q_s}{n^c}\right) = MC\left(\frac{Q_s^t}{n^t}\right) \qquad \forall s \in S \\ p_{d-1} &: \; p_{d-1} = \int_{s \in S} f(s) p_s ds \\ Q_{d-1}, Q_{d-1}^t &: \; p\left(\frac{Q_{d-1}}{n^c}\right) = MC\left(\frac{Q_{d-1}^t}{n^t}\right) \end{aligned}$$

In words: Q_{d-1} settles on a level that does not reflect the cost of maintaining that desired output

Conclusions

Even with speculation, demand participation...

- implements the first-best outcome in the balancing market,
- reduces the risk of a system "crash"

Yet, the cost of balancing the system might be ...

- lower: consumers share the adjustment burden, or
- higher: demand participation has an impact on Q^t_{d-1}

Future work:

- Profit-maximizing wind producers
- Consumer and producer heterogeneity
- Imbalance fees

Main references

AEEGSI, 2016a. Prima fase della riforma del mercato per il servizio di dispacciamento: apertura alla domanda, alle fonti rinnovabili non programabili e alla generazione distribuita. DCO 298/2016/R/eel.

AEEGSI, 2016b. Avvio di procedimento per l'adozione tempestiva di misure prescrittive e la valutazione di potenziali abusi nel mercato all'ingrosso dell'energia elettrica ai sensi del Regolamento (UE) n. 1227/2011 (REMIT). Deliberation 342/2016/E/eel.

AEEGSI, 2017. Prima apertura del Mercato per il Servizio di Dispacciamento (MSD) alla domanda elettrica ed alle unità di produzione anche da fonti rinnovabili non già abilitate nonché ai sistemi di accumulo. Istituzione di progetti pilota in vista della costituzione del Testo Integrato Dispacciamento Elettrico (TIDE) coerente con il Balancing Code europeo. Deliberation 300/2017/R/eel.

Crampes, C. and Léautier, T.O., 2012, May. Distributed load-shedding in the balancing of electricity markets. In 9th International Conference on the European Energy Market (EEM), pp. 1-7, IEEE.

Crampes, C., and Léautier, T. O., 2015. Demand response in adjustment markets for electricity. Journal of Regulatory Economics, 48(2), 169-193.

Just, S. and Weber, C., 2015. Strategic behavior in the German balancing energy mechanism: incentives, evidence, costs and solutions. Journal of Regulatory Economics, 48(2), pp.218-243.