ECONOMICS FOR FLEXIBLE CONSUMERS IN BALANCING MARKETS

Christine Brandstätt
Fraunhofer Insitute for Manufactoring Technology and Advanced Materials (IFAM)
Department Energy System Analysis, Wiener Straße 12, 28359 Bremen, Germany
e-mail: christine.brandstaett@ifam.fraunhofer.de, phone: +49 (0)421 – 2246 7027

Overview
The demand for balancing capacity is expected to increase with rising shares of renewable energy (cf. e.g. Tarroja et al. 2012). Present balancing markets are dominated by and originally designed for flexible generators. Consumers offering balancing capacity are still relatively rare. For future smart electricity systems it will be necessary to harvest their potential contribution. This paper analyses their cost structure (along the example of a power to heat consumer) in comparison to spinning generation reserves (along the example of a gas turbine). It furthermore discusses the effects of some features of the presently predominating market designs on flexible consumers.

Method
The cost functions are derived for flexible consumers and compared to those of spinning reserves. A comparison reveals the cheaper option depending mainly on the relation of spot price and variable cost of the generator. Additionally, the effect of uncertainty due to advance between the balancing and spot market is added to the analysis. Some of the common market design aspects with balancing markets, such as time lag between and sequence of spot and balancing markets as well as scoring rules are discussed based on the mathematical analysis.

Results
The cost functions for spinning reserves, as known for example from Chao & Wilson (2002) or Müsgens et al. (2012 & 2014) depend mainly on the generators' variable cost (VC_{gen}), the spot price received for generated electricity (P_{spot}) and partially also on technical capacity constraints (Cap_{min}, Cap_{bid}) (1). For many flexible consumers the cost of generating the consumed utility in a non-electric manner (VC_{alt}), i.e. in case of an electric boiler the cost of deploying a gas boiler, add to the variable cost of regulating consumption[1] (VC_{con}) (2). Capacity constrains may result from volatile demand for the utility supplied. In case of an electric boiler for example the possibility to provide balancing capacity by regulating consumption depends on heat demand and storage capacity.

		capacity	**energy**	**total**
1) flexible generator	a) $VC_{gen} \leq P_{spot}$	$P_{spot} - VC_{gen}$	VC_{gen}	P_{spot}
	b) $VC_{gen} > P_{spot}$	$(VC_{gen} - P_{spot}) \cdot \frac{Cap_{min}}{Cap_{bid}}$	VC_{gen}	$(VC_{gen} - P_{spot}) \cdot \frac{Cap_{min}}{Cap_{bid}} + VC_{gen}$
2) flexible consumer	a) $VC_{alt} \geq P_{spot}$	0	VC_{alt}	VC_{alt}
	b) $VC_{alt} < P_{spot}$	$P_{spot} - VC_{alt}$	VC_{alt}	P_{spot}
assumptions $VC_{con} = 0$				

Table 1: Cost functions for balancing from flexible generators and consumers

Comparing the cost functions proves balancing from flexible consumers to come at lower energy cost if the cost of supplying the consumed utility in a non-electric manner is lower than variable cost of the spinning reserve. For the example of an electric boiler with a gas backup compared to a gas turbine this seems likely, assuming equal fuel cost but higher efficiency for the gas boiler. The capacity cost is lower for balancing provision by flexible consumers mainly if in addition to the former condition the cost of supplying the consumed utility in a non-electric manner exceeds the spot price (A). On the contrary, for a spot price above the generators variable cost (C) the cost of balancing capacity by the flexible consumer represents the more expensive option. In the price range in between (B), capacity constraints are decisive.

[1] Following the notion of an electric boiler the latter are assumed as zero throughout the paper.

A: low spot price	$P_{spot} \leq VC_{alt}$	$C_{cap\ 2a} < C_{cap\ 1b}$
B: mid-range spot price	$VC_{alt} < P_{spot} < VC_{gen}$	*depends on* $\frac{Cap_{min}}{Cap_{bid}}$ *and* $\frac{VC_{alt}}{VC_{gen}}$
C: high spot price	$VC_{gen} \leq P_{spot}$	$C_{cap\ 1a} < C_{cap\ 2b}$

Table 2: Cost comparison for various spot prices ranges (in relation to variable cost)

The effect of uncertainty about spot prices at the time of commitment for balancing is lesser for flexible consumers than for generators. For generators the commitment not to offer a certain capacity in the spot market without knowing the price holds the potential of forgone revenue if the spot price turns out more attractive than anticipated. At the same time having to sell a certain capacity in the spot market (in order to 'keep spinning') holds the risk of not recovering variable cost if the spot price turns out less attractive than expected. The sum of both those risks will be added by the generator to his bid and hence increase capacity cost. A consumer, however, only faces the risk of having to generate the utility electrically when it could have been supplied cheaper in a non-electric manner, in case the spot price turns out higher than expected. Considering the mark-up for each of the identified risks to be the same, the total mark-up on the consumer's bid is only half of the generator's.

Conclusions

In view of increasing shares of fluctuating renewable electricity generation and consequently rising demand for balancing capacity, it is a topical concern to introduce flexible consumers as suppliers of balancing capacity. In times of high availability of fluctuating renewable energy sources spot prices are typically low and hence according to the analyses balancing from consumers will be more efficient than from generators. In addition flexible consumers's mark-ups due to price uncertainty appear lower than those of generators. A market design with fewer advances for bid submission is nonetheless expected to work in favor of flexible consumers as uncertainties about availability of capacity reduce close to delivery time. Furthermore a balancing auction after (instead of before the spot market) facilitates bidding for consumers. Scoring based on capacity inefficiently favors generators in case of high electricity prices (higher than variable cost). In this case capacity cost is lower for the generator while total cost (including energy cost) is equal for both.

Alterations of market design may hence achieve higher contribution of flexible consumers in balancing markets. However, market design is likely not the only lever to improve integration of demand flexibility into balancing. The role of for example aggregators and service providers as well as that of smart technology in this respect still needs exploration.

References

Chao, H.P. and Wilson, R. (2002): "Mulit-Dimensional Procurement Auctions for Power Reserves: Robust Incentive-Compatible Scoring and Settlement Rules" Regulatory Economics 22(2): 161-183.

Müsgens, F., Ockenfels A. and Peek, M. (2014) "Economics and design of balancing power markets in Germany" Electrical Power and Energy Systems 55: 392-401.

Müsgens, F., Ockenfels A. and Peek, M. (2012) "Balancing Power Markets in Germany: Timing Matters" Zeitschrift für Energiewirtschaft 36: 1-7.

Tarroja, B., Müller, F., Eichman, J.D. and Samuelsen, S. (2012) "Metrics for evaluating the impacts of intermittent renewable generation on utility load-balancing", Energy 42(1): 546-562.