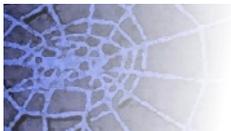


The evolution of smart grids and the increasing need for disaggregated nodal pricing

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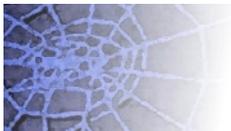
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Motivation

Two lines of institutional reforms can be observed in European energy policy:

- (1) market liberalization and competitive decentralized electricity generators. Market liberalization opens up possibilities for decentralized, competitive generators of renewable energy.
- (2) the political support of electricity generation by means of renewable energy sources. Incentive compatible integration of microgrids and distributed energy into smart grids.

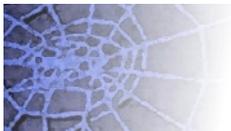
Both lines increase the need for time sensitive and locational differentiated congestion management in electricity networks.



Disaggregated nodal pricing (1)

In contrast to integrated nodal pricing reflecting the total value of electricity consisting of generation and transmission costs at different nodes, disaggregated nodal pricing consists of three separate elements:

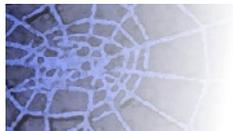
Firstly: electricity transmission prices raised by the network carrier, consisting of node-dependent injection and extraction prices based on system externalities. System externalities changing power loss and network scarcity are the opportunity costs of electricity injection or extraction depending on the node (location) where generation or extraction takes place.



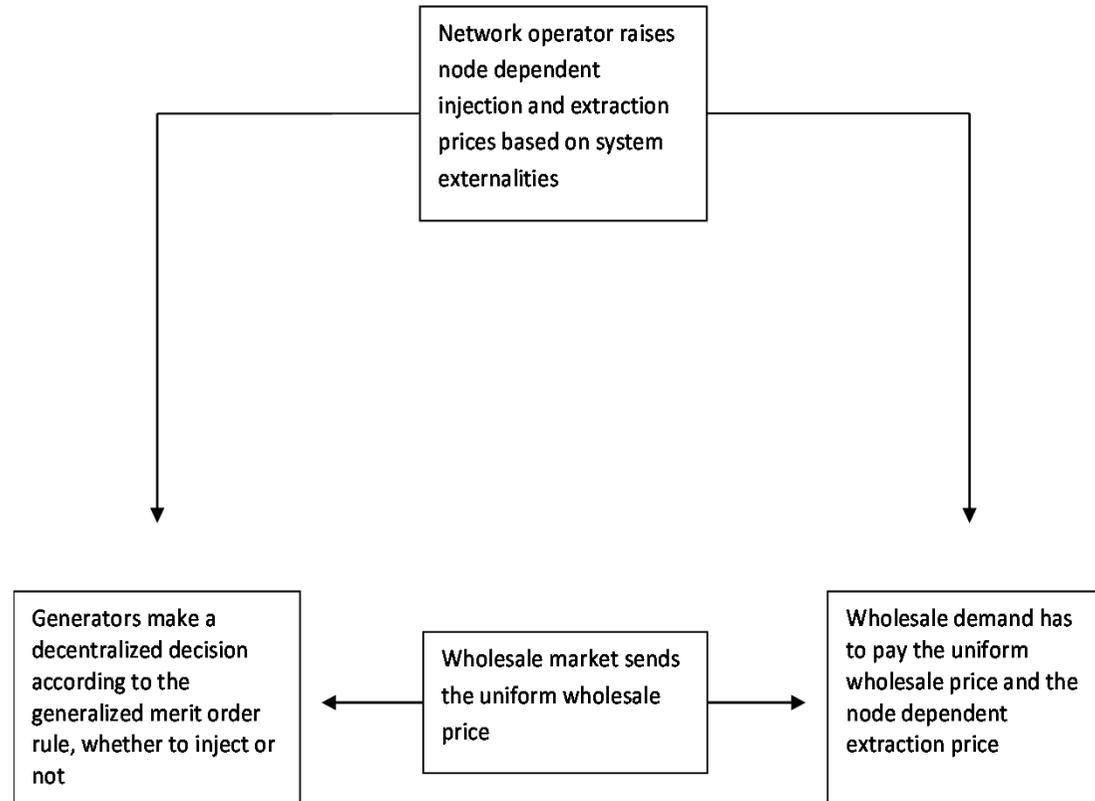
Disaggregated nodal pricing (2)

Secondly: the generalized merit order indicating at which nodes injection is worthwhile so that generation costs and injection price do not exceed marginal willingness to pay on the wholesale market.

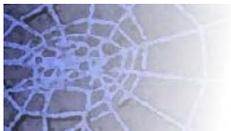
Thirdly: nodal prices at extraction nodes reflecting the sum of the (uniform) wholesale price and node-dependent extraction price.



Disaggregated nodal pricing (3)

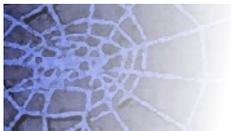


Source: based on Knieps 2013, pp. 156 ff.



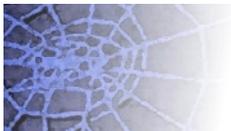
Transactive energy and smart distribution networks (1)

- The transition to microgrids and transactive energy shifts the focus to an active role of distribution networks. Driven by bottom up injection from microgrid nodes active management of all injection sources including stand-alone renewable resources and conventional energy sources becomes necessary. The proper incentives for generation at the right place (node) and the right time become highly relevant, no longer only for (high voltage) transmission networks but also for (medium voltage) distribution networks.
- Each distribution network has its own network constraints and system externalities at the different nodes. Injection takes place either via import from a transmission network, or via injection by a generator at the distribution level or via a microgrid (or Virtual Power Plant) node.
- The wholesale markets of electricity injected into the (high voltage) transmission network has to be differentiated from the wholesale market of electricity injected into the (medium voltage) distribution network resulting into generalized merit orders at different network levels.



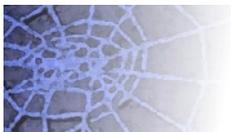
Transactive energy and smart distribution networks (2)

- The opportunity costs of injection and extraction at a microgrid node cannot be considered in isolation; instead the system externalities of injection or extraction due to the change of scarcity within the whole distribution network have to be taken into account.
- In contrast, within retail markets on (low voltage) local networks no system externalities are relevant, therefore the individual locations of the prosumers within a microgrid is not relevant. Instead only the total net consumption or net production measured by the aggregator and forwarded to the microgrid node at specific time intervals are considered.



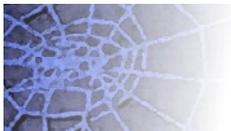
Decentralized interaction between different network levels

Injection on different levels		Wholesale markets	Retail market
→	Transmission network	High voltage electricity	
	↑↓		
→	Distribution network	Medium voltage electricity	
	↑↓		
→	Microgrid /Local network		Low voltage electricity



Real time generalized merit order for wholesale markets on the distribution networks

- In order to provide the proper economic incentives for prosumers and other consumers the real time opportunity costs of extraction or injection into the microgrid node within the distribution network are relevant.
- Real time allocations bundled by an aggregator are online interrelated with the distribution network, thereby causing positive or negative real time system externalities to the distribution network.
- The real time allocation of microgrid energy requires real time node-dependent injection and extraction pricing not only at the microgrid node, but within the whole distribution networks.
- The opportunity costs of prosumer activities are determined by the opportunity costs of outside conditions at the distribution network based on the real time generalized merit order for the wholesale market.



References

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