Distribution grid congestion management

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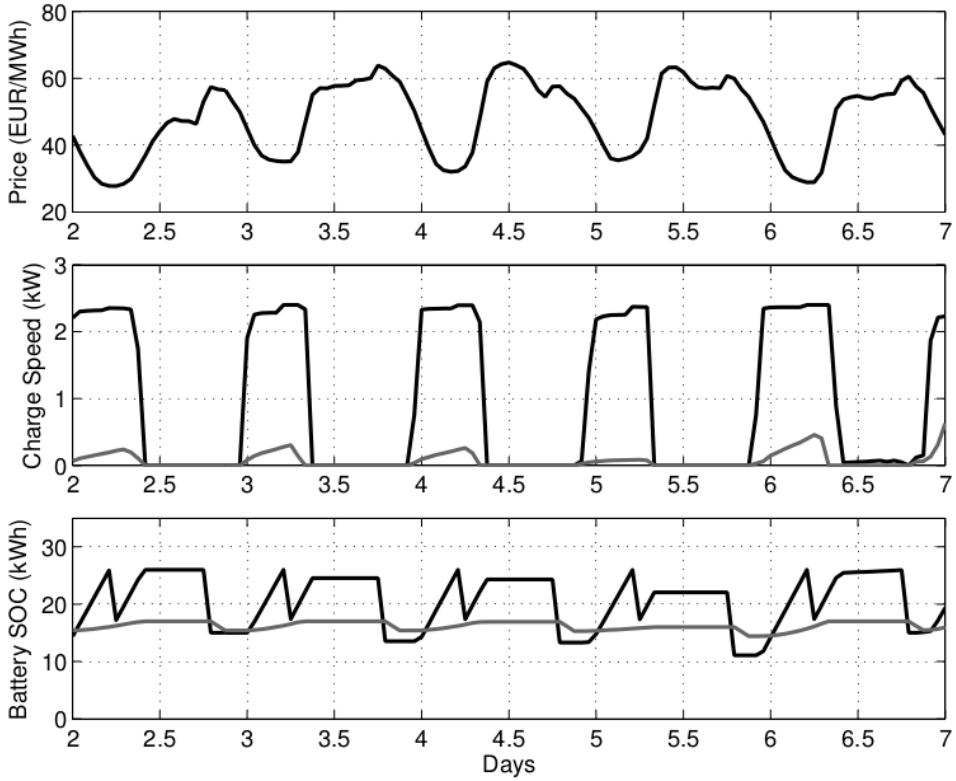
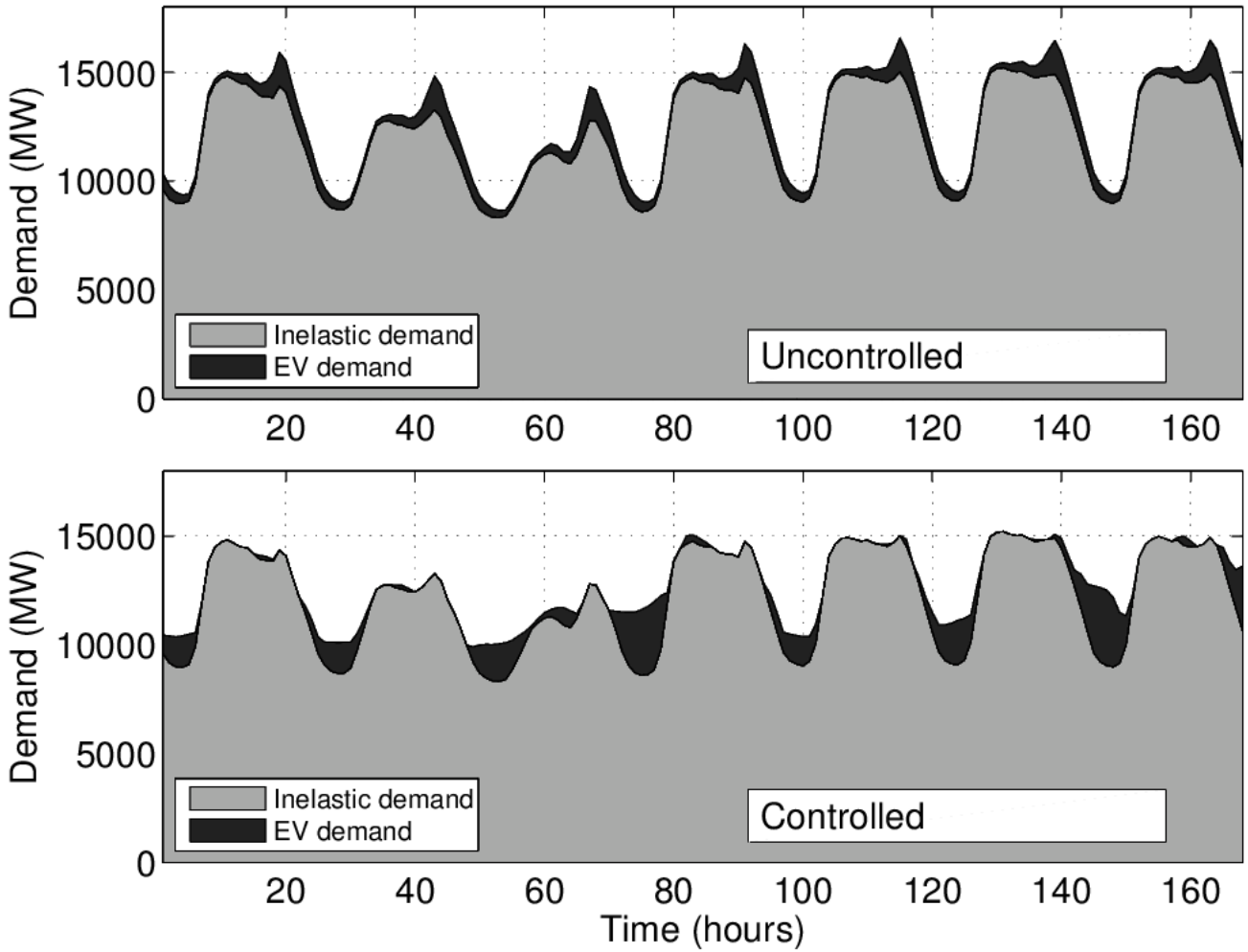
Demand response

“Flexible electricity demand reacting/anticipating on certain signals”

Example: EVs anticipating on electricity price

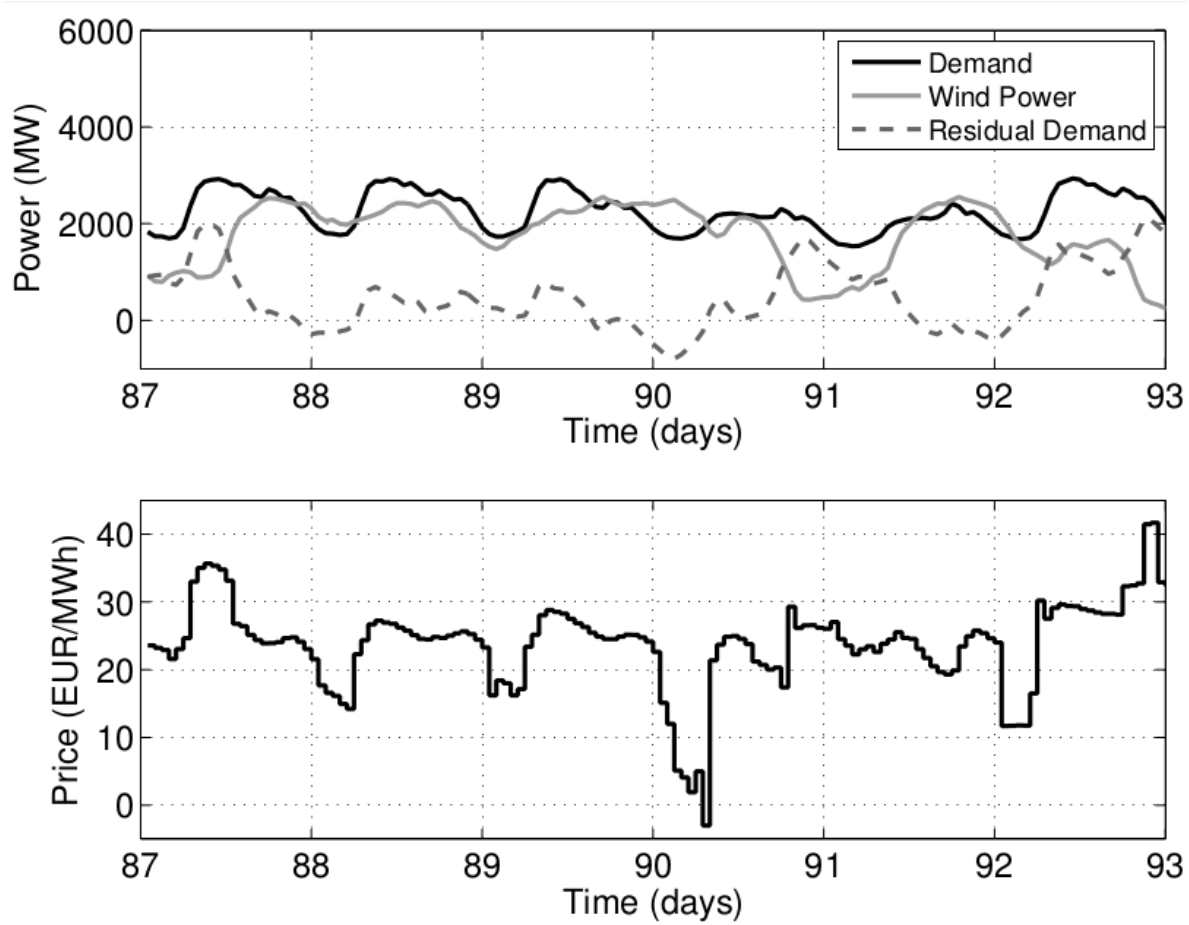


EV demand profiles on a national level (25% EVs)

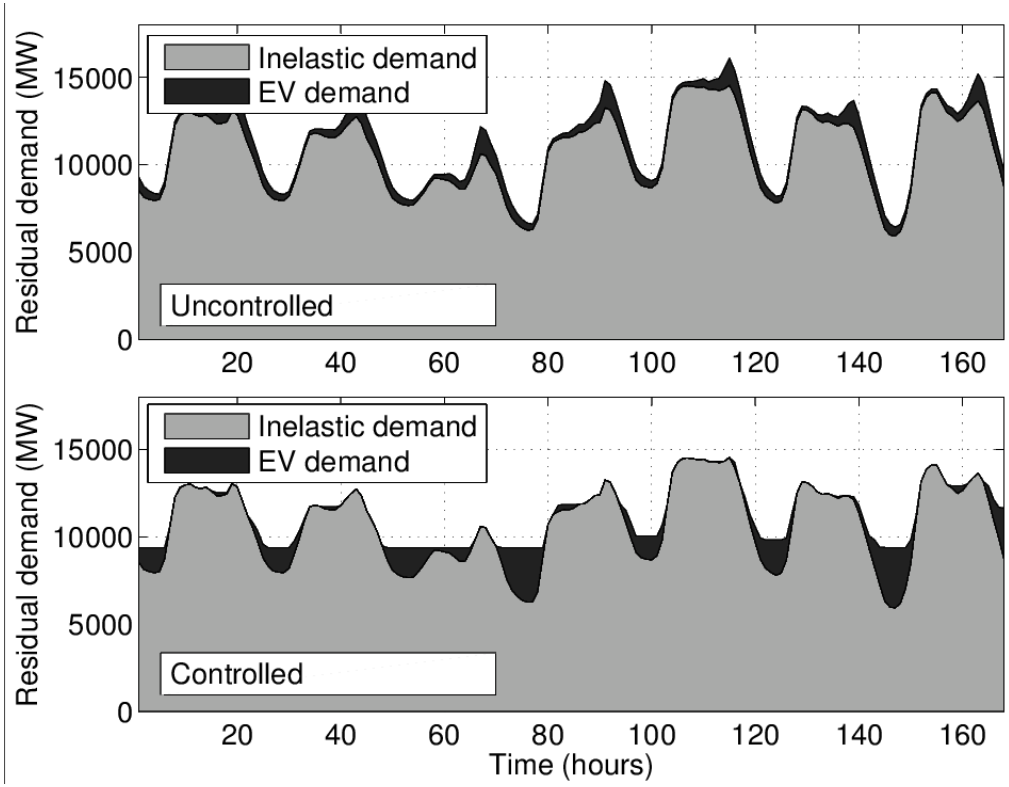


Residual load determines electricity price

Example from Danish system

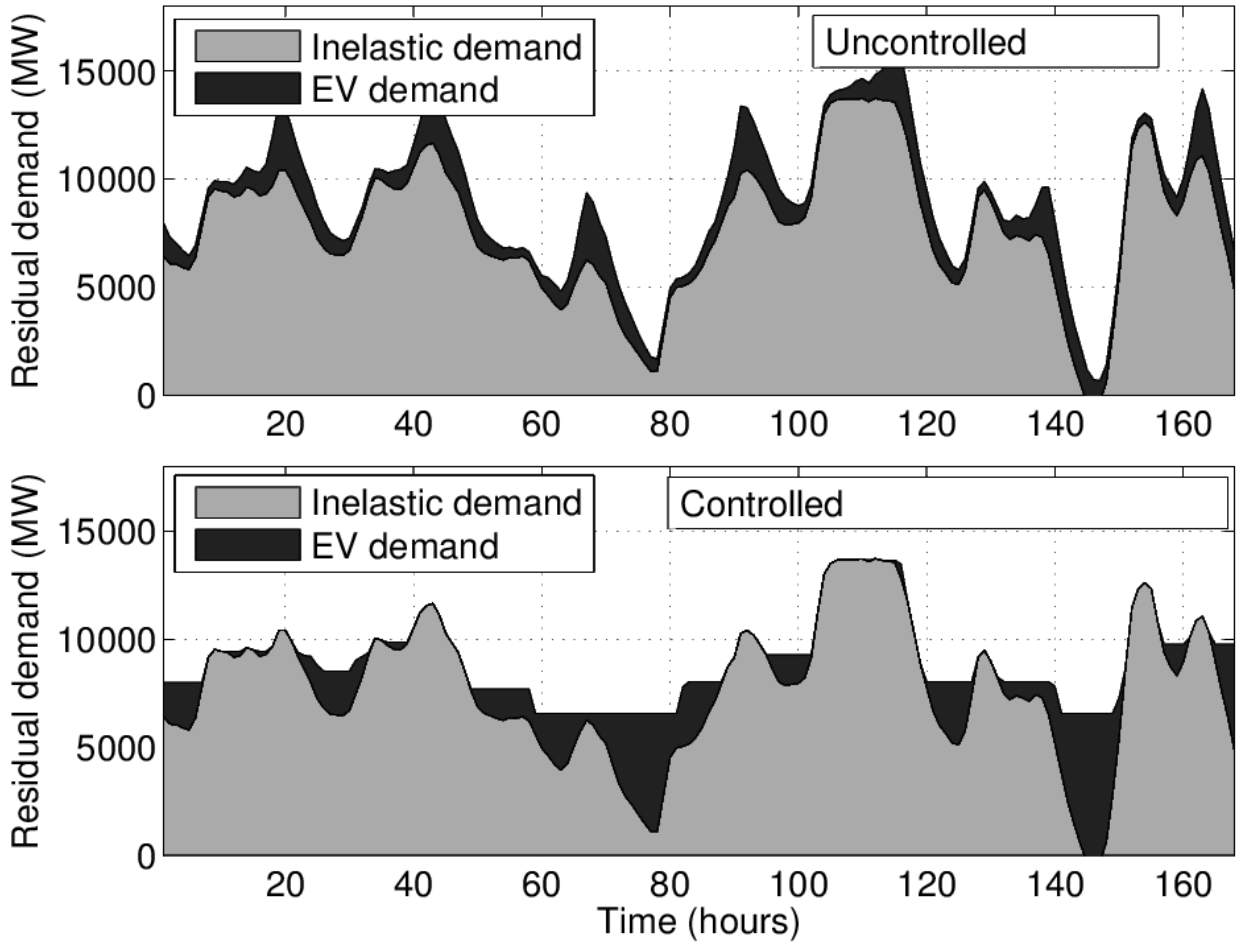


EVs and residual load profiles (5GW wind, 25% EVs)

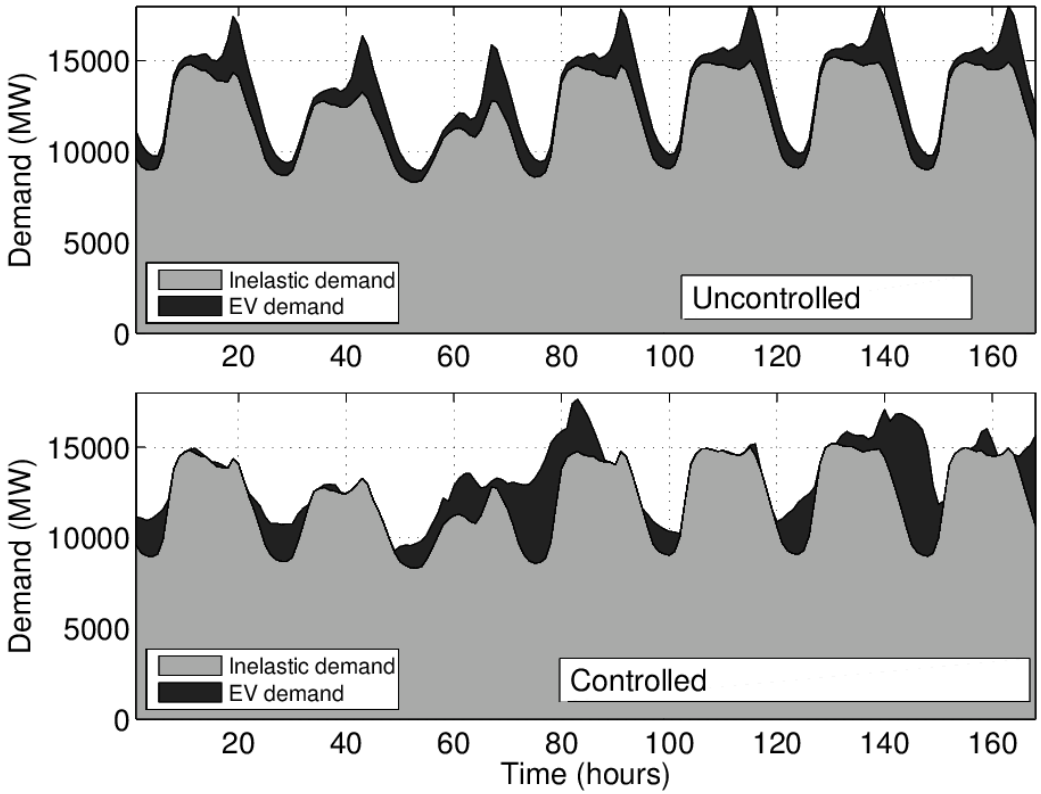


'Valley filling'

More filling material (50% EVs) and deeper valleys (15GW wind)

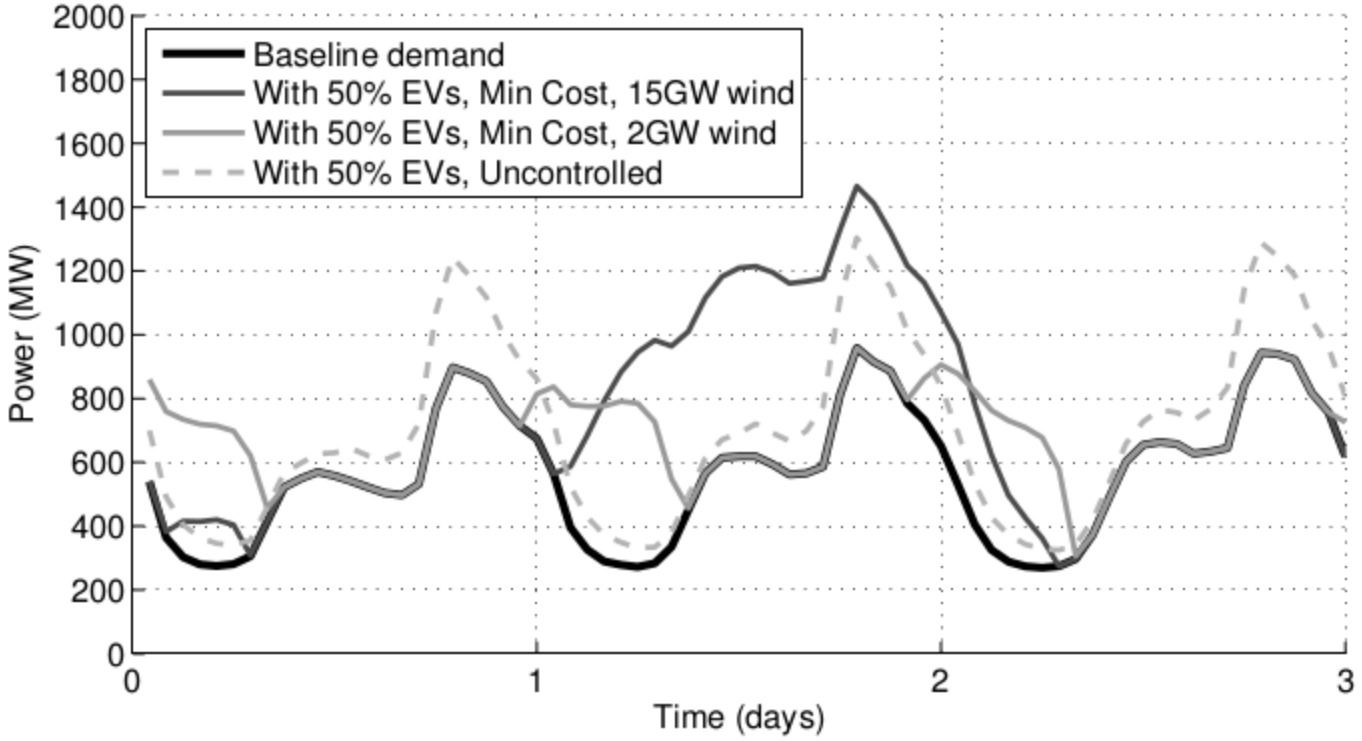


Load (≠residual load!) and EV load



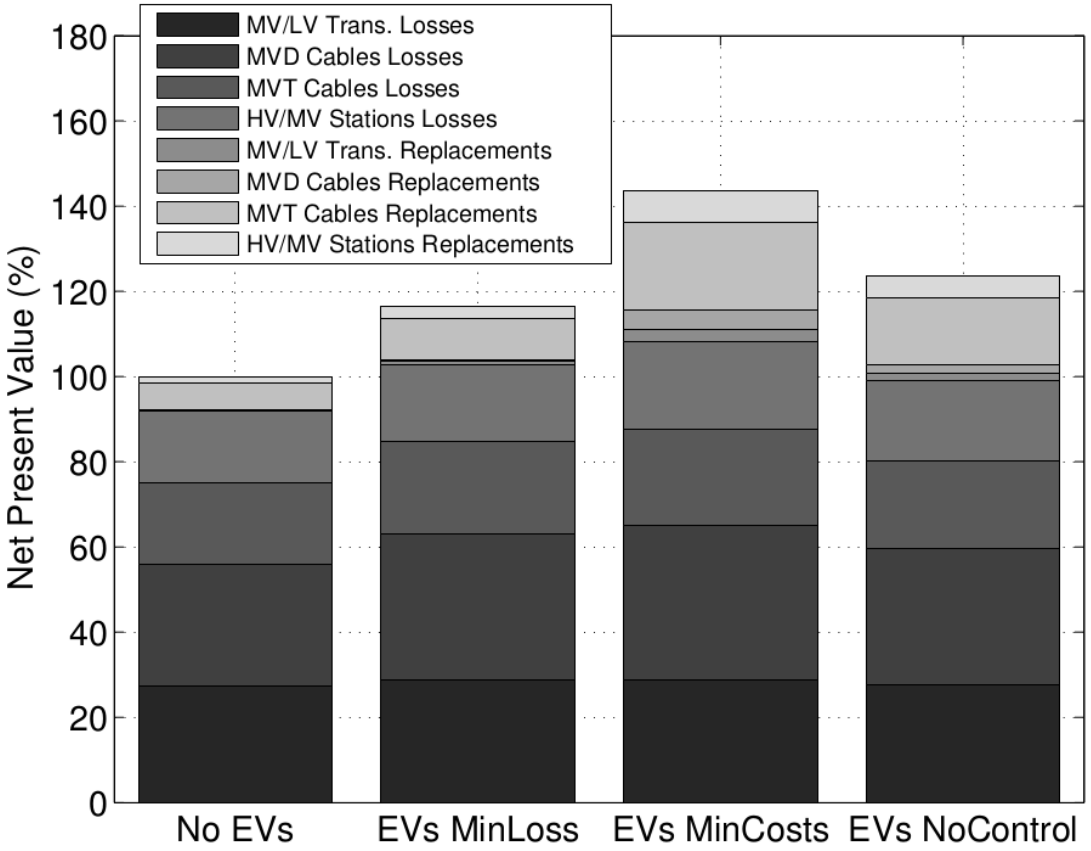
EVs reacting on low prices cause peaks in demand:
“load clustering”

Network load with 'smart' EVs



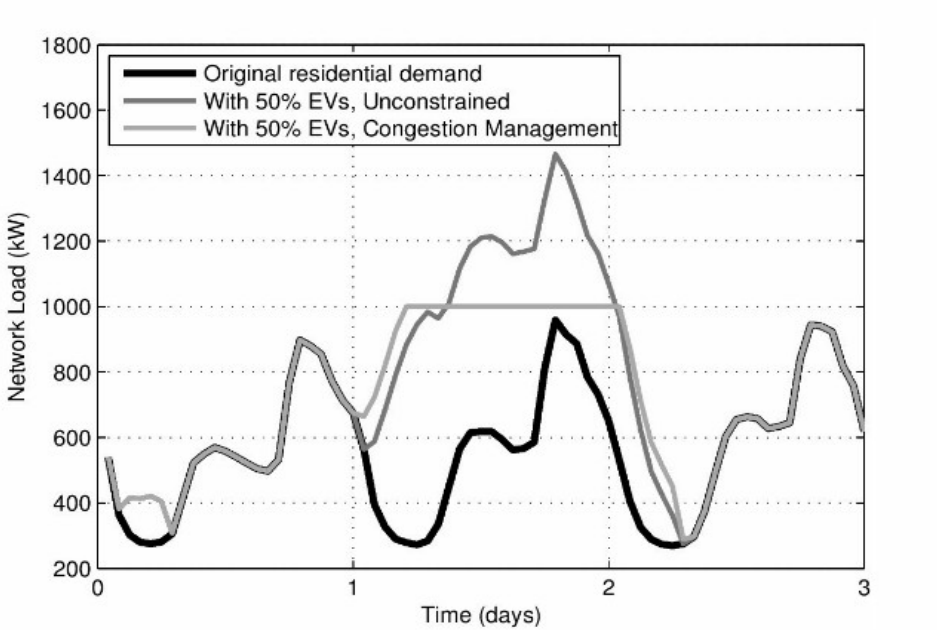
Consequence for the network

E. Veldman and R.A. Verzijlbergh "Distribution Grid Impacts of Smart Electric Vehicle Charging from Different Perspectives" *IEEE Transactions on Smart Grid.* vol.6, no.1, pp.333,342, Jan. 2015



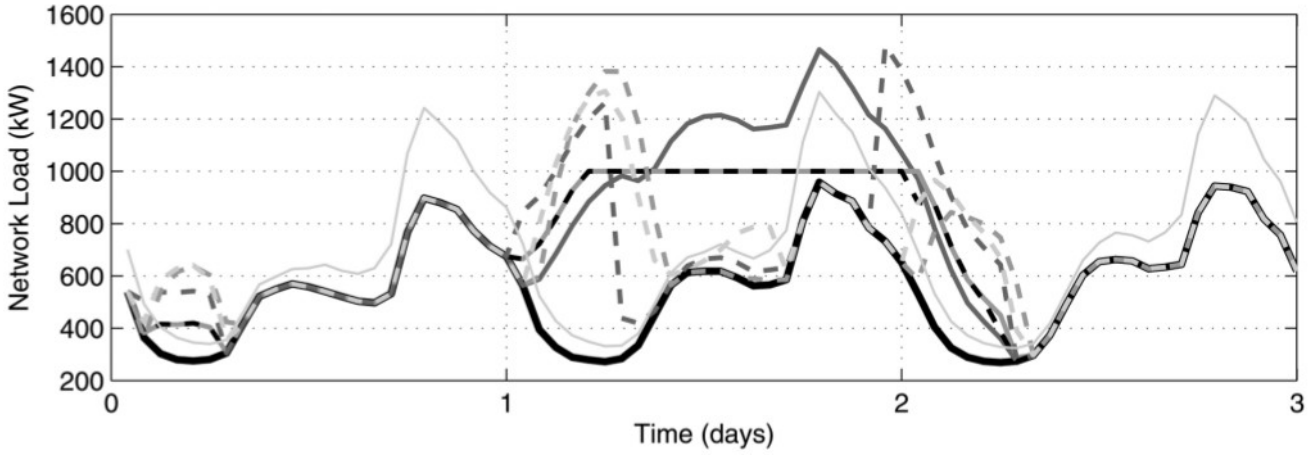
Reducing generation costs increases network costs.

What if we limit EV load to network capacity?



	Constrained	Unconstrained
Peak demand	100%	150%
Network costs	100%	130%
Energy costs	100.5%	100%

Simple tariffs don't work



	Contrained	Unconstrained	Simple tariff
Peak demand	100%	150%	155%
Network costs	100%	130%	(> 130%)
Energy costs	100.5%	100%	120%

The main question

Renewable Energy Sources and Responsive Demand. Do We Need Congestion Management in the Distribution Grid?

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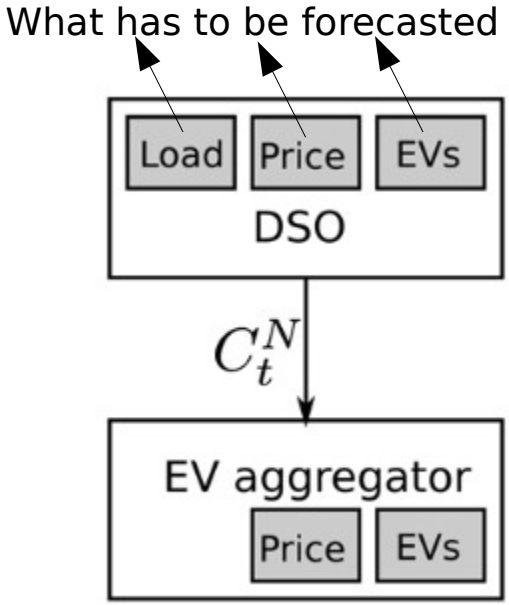
Design variables for congestion management

- Price vs. quantity
- Single shot vs. iterative
- (DSO-consumer vs.) **DSO-aggregator** (-consumer)
- **Blocks of time-steps** vs. single time-steps sequentially

Performance criteria

- Economic efficiency
- IT requirements
- Computational feasibility
- Performance under uncertainty

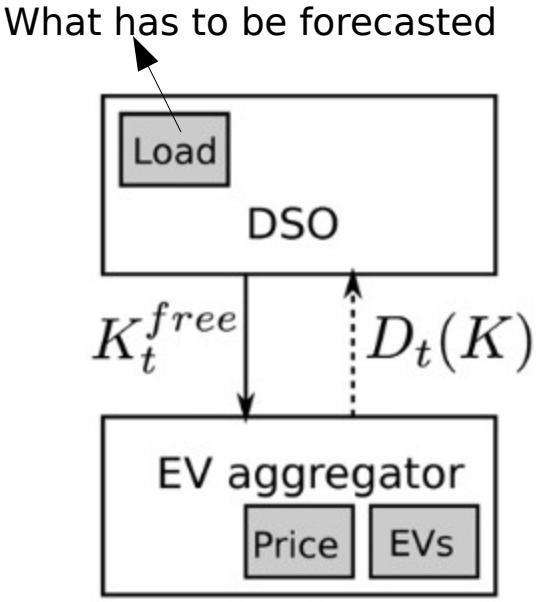
Option 1. Price based, single shot: “Dynamic grid tariff“



- DSO 'knows' all wholesale prices, EV preferences (i.e. aggregator response function)
- Determines the optimal network tariff by solving a bi-level programming problem
- Aggregator determines optimal EV load

C_t^N denotes a time varying network tariff

Option 2. Capacity based, single shot. “Advance capacity allocation”



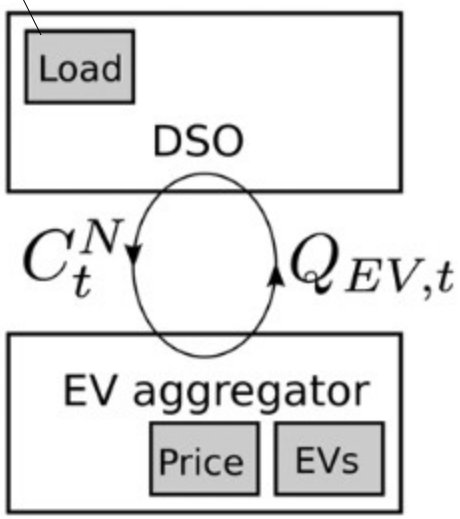
- In case of a single aggregator: DSO simply allocates free network capacity to aggregator
- In case of multiple aggregators: aggregators have to bid demand functions.

$\bar{K}_t^{free}$ available network capacity

$D_t(K)$ a demand function for network capacity

Option 3 : Price based, iterative. “Distribution grid capacity market”

What has to be forecasted

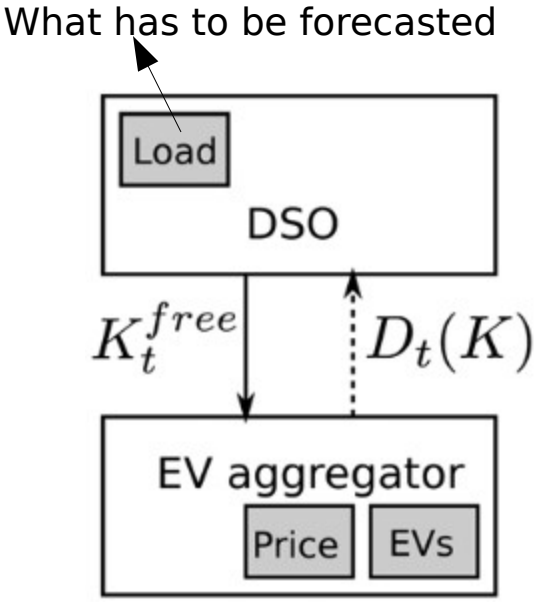


- DSO starts with a first guess
- Aggregator(s) determine optimal EV load
- New prices calculated
- etc

C_t^N denotes a time varying network tariff

$Q_{EV,t}$ denotes EV load

Option 4? Capacity based, iteratively. Is this the same as option 3?

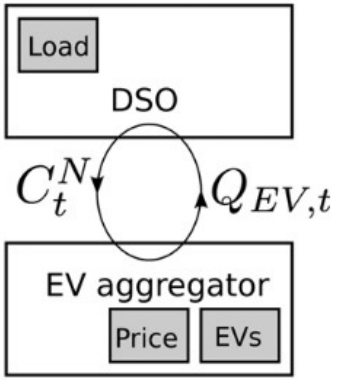


- In case of a single aggregator: DSO simply allocates free network capacity to aggregator
- In case of multiple aggregators: aggregators have to bid demand functions.
- The problem lies in the **intertemporal dependency** of the demand functions

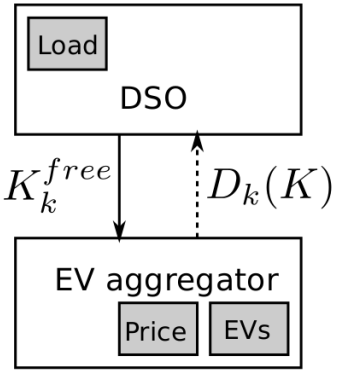
$\bar{K}_t^{free}$ available network capacity

$D_t(K)$ a demand function for network capacity

Trade-offs between congestion management schemes



(c) Iterative distribution grid capacity market



(b) Advance capacity allocation.

"Power Matcher"
Complex IT required
Scalable to many aggregators
Economically efficient

"Enexis Mobile Smart Grid"
More straightforward
Difficult for more aggregators
Most 'robust' for uncertainty

More research needed!

Conclusions

- Congestion management seem attractive: constraint is cheap, but the network costs are high (if unconstrained)
- Simple tariffs don't work: distort economic signal and don't solve congestion
- Conclusive answer on best congestion management method needs more research:
  - Solar PV
  - Uncertainty
  - Relation network cost recovery and congestion rents
  - More detailed mechanism design