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DEALING WITH LARGE NUMBERS OF SYSTEM PARTICIPANTS

Due to the rising penetration of photovoltaic generation units, battery-electric vehicles, heat pumps, battery storages, and other technologies that can be controlled when necessary from a grid perspective, the number of active system participants is growing exponentially. However, today's operational concept and market design is not suited to accommodate large numbers of participants as they were originally developed for the traditional configuration of the energy system. In practice, this means that many opportunities for flexibility in the energy system are unused, simply because they are not known to the proper institution. Also, these system participants themselves can forecast their energy demand or generation relatively easily, in contrast to the central system operator who must make assumptions about time of use etc. Consequently, the central system operator's forecasts are unnecessarily uncertain since better forecasts exist but are not properly communicated.
Solutions have been offered, such as local energy or flexibility markets, microgrids, and energy communities. These concepts usually mitigate the issue of integrating large numbers of active system participants well but often come with two major disadvantages. For one, they often introduce sequential markets that are cleared first on a local level and afterwards on a global level. Such constellations are prone to harmful arbitrage behaviour, e.g., "inc-dec" gaming. Second, since these concepts focus strongly on local flexibilities, economically attractive transmission capabilities may remain unused. "Smarter" congestion management methods are also being developed, incorporating more and smaller units (e.g, "Redispatch 3.0"), and effectively solving congestion issues. However, as congestion management measures become more frequent, this approach appears inefficient and is also not very attractive to end customers.
One possible solution to this problem is to view the energy system as a "system of systems" that is decomposed into hierarchically ordered subsystems delimited by system level and geographical extent (often called "cells", hence this concept is also called "web of cells" or "cellular energy system"). On each system level, the subsystems have different tasks.

- End customers:
  - Internal optimisation based on forecasts and energy prices,
  - Submission of optimization results to higher system levels (e.g., as bids),
  - Internal responsibility for safe and secure operation and,
  - Responsibility to support higher level's tasks

  Goal: achieve cheapest possible energy supply using internal flexibilities
- Local system level:
  - Aggregation and disaggregation of bids (from below) and results (from above)
  - Local responsibility for safe and secure operation

  Goal: utilisation of local flexibilities
- Central system level:
  - Market-clearing (security constrained economic dispatch) on day-ahead and intra-day time basis
  - System responsibility (esp. active power balancing)
  - Ancillary services

  Goal: utilisation of transmission capabilities

Between the system levels, data exchange is kept to a minimum as only optimisation results or aggregated results must be exchanged with other parts of the system. Therefore, the amount of data is manageable for individual subsystems and the communication infrastructure. At the same time, harmful arbitrage behaviour is prevented since all bids by subsystems end up the same market-clearing process (some directly, some aggregated). Finally, both use of local flexibilities as well as transmission capabilities is incentivised by this scheme, ideally using economic methods such as local marginal pricing.