On the market conditions rendering Demand Response attractive to all involved actors

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i. Overview

Demand Response (DR) aims at rescheduling consumers' consumption such that their loads are aligned with renewable production, grid status and suppliers' balance. There are several types of DR schemes available for motivating the active participation of consumers. In *explicit DR* campaigns, consumers agree to adjust their load for specified periods of time either manually (e.g., by delaying energy-intensive appliances such as washing machines) or automatically (e.g., by allowing a third party to remotely control the room temperature with minimum impact on its comfort level). For both schemes, MDR and ADR campaigns respectively, the consumers are compensated for the flexibility offered to the grid. In *implicit DR* campaigns though, consumers select a plan, such as Time of Use (ToU), Critical Peak Pricing (CPP) and Real-time Pricing (RTP), where prices fluctuate according to the wholesale markets and thus they are motivated to offer their flexibility for reducing their bills.

Regardless of the contractual details, DR is considered as a promising alternative to traditional, supply-side management techniques to all market actors. For example, DR provides the capability to distribution system/network operators (DSO/DNO) to communicate the appropriate (price) signals and relief their grid from periods of extensive congestion which are mainly responsible for the power losses. As a consequence DSOs can defer, or even avoid, the investments for capacity upgrades (grid lines, transformers and home connectivity). For example, a recent study found that the current grid infrastructure can cope with the hypothetical 100% electrification of the European transportation fleet, under the assumption that EV charging does not coincide with peak demand). Similarly, retailers that aim for a balanced portfolio of their clientele, may utilize demand-side management techniques instead of relying on intra-day markets, or pay penalties for their imbalances. Last, but not least, the legislative framework in the European Union, requires from the Member States to remove all the barriers that prevent the development of DR mechanisms, and to guarantee its non-discriminatory participation along with the supply in the wholesale markets.

In this paper we will focus on explicit DR campaigns and the market conditions that can render them financially attractive to all involved actors, namely Consumers, Aggregators, DSOs and Retailers. This is important as a recent study concludes that explicit DR has not been developed at a satisfactory level.

i. Methodological approach

We developed a simulator of a (hypothetical) consumer's decisions regarding energy consumption that considers several factors, which include, but are not limited to:

- contracts with other market actors like Aggregators for providing flexibility when asked;
- technology (such as smart controllers for participating in Automated Demand-Response campaigns),
- residents' habits in terms of absence hours, price elasticity or willingness to join Demand-Response campaigns.

This simulator provided us valuable insights on several DR-related performance metrics, such as the flexibility that can be obtained during a MDR/ADR campaign, in a wide range of scenarios.

The 12 scenarios defined make assumptions on the following market aspects:

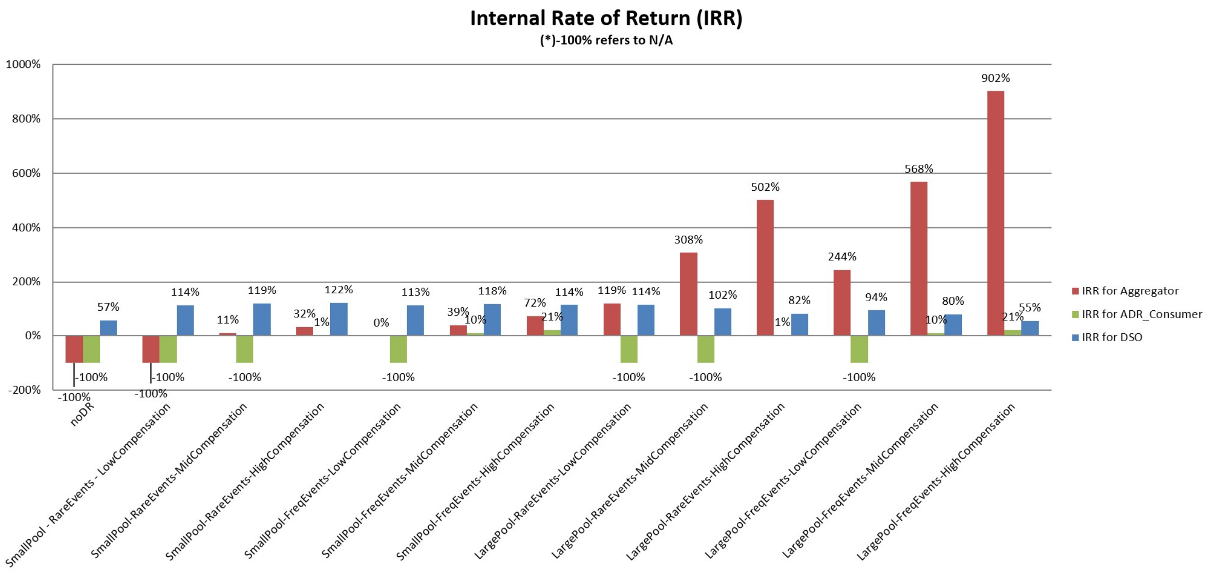
1. size of the Aggregator's participants pool (low, high)
2. frequency of requests for DR (low, high)
3. DR compensation level and its effects on the flexibility obtained (Low, Mid, High)

Furthermore, an additional scenario was defined for simulating the Business-as-Usual case, where only supply-side management techniques are used. Then, for each of those 12+1 scenarios we defined the value networks and the associated business models of the entities involved. In particular, we quantified the main revenue streams and cost items of each entity in each scenario in order to compute cash flows and eventually evaluate the financial attractiveness and feasibility of each alternative via key financial indicators. For this purpose, we used our powerful and extensible "what-if" scenario engine, called NobelGrid business model evaluation tool, which aims at:

- Evaluating business models enabled by innovative smart grid technologies;
- Evaluating the replication & upscaling of technologies, and
- Evaluating the Cost-Benefit of technologies.

ii. Results

The following figure presents the financial attractiveness, in terms of the Internal Rate of Return, of each scenario for a hypothetical ADR consumer, Aggregator and DSO. Each instance of the first actor has installed a smart-home controller and enrolled in an ADR contract and she receives €0.1 (lowCompensation), €0.2 (midCompensation) and €0.3 (highCompensation) for each kWh of flexibility delivered. The Aggregator is assumed to have a community of 1000 and 10000 members (smallPool/largePool respectively). Furthermore, each pool has a balanced mix of both ADR and MDR consumers (the latter do not appear on the figure as no investment needs to take place and thus IRR cannot be computed). The DSO has 65000 customers and to deal with grid instability issues considers either to invest in network upgrade (that costs €1M), or buy flexibility from the Aggregator for €0.2 (lowCompensation), €0.4 (midCompensation) and €0.6 (highCompensation) for each kWh. The Aggregator keeps shares evenly the revenues with the consumers that participated.



i. Discussion and conclusions

From the figure above we see that all scenarios are viable for the DSO, both the Business-as-Usual, as well as the DR-enabled ones. Interestingly, the latter ones outperform the "noDR" scenario in all cases but the one where DR events happen very frequently, a large pool of participants results in 99% probability of meeting the requested flexibility but at a relatively high DR campaign cost. These results provide evidences that DR campaigns can help the efficient management of the smart grids. However, not all of them are feasible ones as one, or more, of the rest actor types would not find it attractive enough to participate. For example, according to our assumptions, all scenarios with lowCompensation are not appealing to ADR_consumers. On the other hand, all cases with highCompensation are feasible ones, but increasing the compensation to DR participants would make it even more favourable for them without affecting significantly the Aggregator's financial performance. Thus, behavioral energy economics will be key for the uptake of DR campaigns in the future.

In the full version of the paper we will perform Monte-Carlo simulations in order to check the validity of those results for varying assumptions on DR performance aspects, as well as, key costs items and revenues.