Handling of the Rebound Effect in Independent Aggregator Framework

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***Abstract*—After the adoption of the new Electricity Directive, European countries are working towards establishing legal frameworks for independent aggregation of demand response, including the rules related to the transfer of energy process, settlement organization between suppliers, independent aggregators and their respective balance responsible parties, and other important issues. One noteworthy issue is the rebound effect – change in the consumption pattern opposite and shifted in time from the demand response event. The rebound effect can cause significant financial consequences. This paper compares various alternatives for the consideration of rebound effect and provides a simulated case study to assess its potential financial impacts. While, in a worst-case scenario, the impacts on suppliers are considerable, moving these additional costs to the aggregators could significantly diminish or outright suspend their development.**

***Index Terms*—Aggregation, Balancing, Demand response, Flexibility, Rebound effect**

I. INTRODUCTION

The EU Clean Energy Package fully adopted in 2019 calls for legal frameworks in EU member states to be developed enabling the participation of demand response (DR) through aggregation in various ancillary services and other organized electricity markets. Furthermore, the Directive (EU) 2019/944 on common rules for the internal market for electricity (Electricity Directive) stipulates that electricity end-users must be free to engage in contracts with aggregators without the consent of their suppliers [1]. In practice, this requires the processes regarding independent aggregator operation and relations with other market participants to be clearly established.

In essence, an aggregator is an electricity undertaking which combines the flexibility of electricity consumers and prosumers to trade in various electricity markets or for system services provision. However, the key feature of independent aggregators specifically is that they are not contractually bound to the suppliers providing electricity to the consumers. This is thereby a decisive difference from the so-called integrated aggregators, whereby the aggregator and supplier are closely related or even the same entity [2].

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While there are a number of European countries where independent aggregators can already operate in some markets (e.g., France, Belgium [3]), other member states are only just beginning to develop the rules related to the transfer of energy (ToE) process, settlement organization between suppliers, independent aggregators and their respective balance responsible parties (BRPs), baselining and other key issues.

Various different independent aggregator models have been analyzed in academic and industry literature [2], [4]–[8]. They are usually classified according to distinct characteristics, but in the broader sense until recently it was possible to group them in three clusters [7] as in Figure 1, based on two features – whether imbalance volume correction to the BRP of the consumer/ its supplier is to be made in case of third-party aggregated DR activation; and whether a compensation payment needs to be made to reimburse the electricity purchased but not sold because of DR activation.

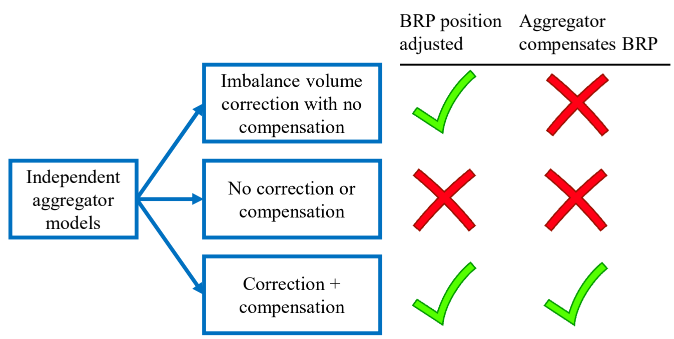

Figure 1. High-level classification of independent aggregator models

However, since the adoption of the new Electricity Directive, the independent aggregators are mandated to be themselves balance responsible parties (or contract with BRPs) [1], thereby, at first glance, the high-level classification has been made narrower, as the question on whether to perform an imbalance volume correction is implicitly answered positively. In terms of the other question – the compensation payment – various models on how to implement the settlement related to it have been proposed [4], however, a centralized settlement model, whereby the cash flows related to the compensation are managed by a central entity (e.g., the transmission system operator (TSO) or an independent organization) seems to be prevailing [2], [5].

In terms of the practical issues which need to be solved for successful independent aggregator implementation, the workstream by USEF [4] lays out the important matters and proposes possible solutions. One such issue which is sometimes unduly neglected when discussing independent aggregation is the handling of the rebound effect (sometimes also called recovery effect [9]). This should not be confused with the term of the same name used in the field of Energy Efficiency, whereby it indicates paradoxically increased consumption caused by efficiency gains [10]. Instead, when discussing explicit DR (as is relevant for aggregators), the rebound effect implies a change in consumption shifted in time from a DR activation event, and in the opposite direction of the event. For instance, as illustrated in Figure 2, a consumption decrease at one point (e.g., because of DR activation for power system balancing purposes) can cause a consumption increase at a later point in time. The rebound effect is not universal, i.e., the existence and parameters (time delay, volume, duration) of it depend on the type of load, e.g., no rebound should be expected from lighting reduction, but it is conceivable in case of thermostatic load.

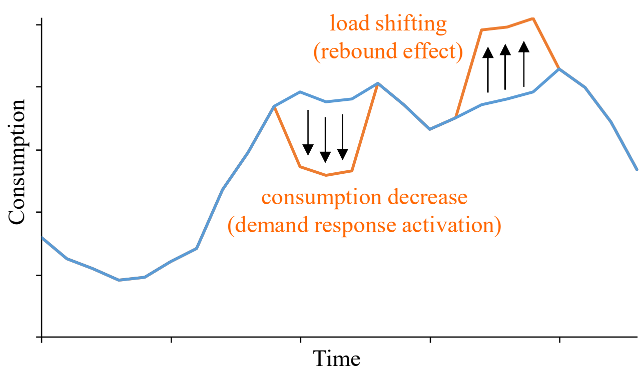

Figure 2. An example of the rebound effect

The rebound effect is seldom considered in aggregator model assessments when calculating the impact of the compensation payments on the parties concerned, with some exceptions, e.g., [7]. This paper compares various alternatives for the consideration of rebound effect and provides a simulated case study based on the energy market situation in Latvia, where an independent aggregator framework is currently under discussion. As a result, recommendations are made for the framework, which can also be extended to a wider European context.

II. Addressing the Rebound Effect in Settlement

There is a number of ways how the rebound effect can be included in the ToE mechanism and the corresponding settlements between market parties. For instance, as laid out in [4], the following options are conceivable:

1) transferring the financial responsibility for the rebound effect to the aggregator's BRP, e.g., by extending what is considered to be the activation time to also include the rebound time (i.e., during this time, the aggregator has balance responsibility for deviations from the baseline that are not the DR activation itself;

2) organizing a compensation payment between the independent aggregator and the supplier which also considers the financial effect on the supplier during the rebound time, i.e., including the rebound risk in the transfer price methodology for the ToE;

3) ignoring the rebound effect for settlement purposes. In this case, however, additional information might have to be shared with the supplier/its BRP in order to allow them to take mitigating actions to cover the rebound risk, e.g., by trading in the intraday market.

To successfully implement the first option, fairly precise temporal characteristics of the rebound effect of a particular consumer/consumption device would have to be known and registered. For such purposes, new actors, like a Flexibility Register [11], where the technical characteristics of DR assets (including rebound characteristics) can be stored, could prove to be very useful. Furthermore, having these parameters registered and available could enable flexibility users (e.g., system operators) to actually include the rebound characteristics already in either their product descriptions or prequalification procedures. This is particularly important in potential congestion management markets, where by solving a congestion issue with DR activation there is risk to induce a new congestion issue during the rebound time. Of course, precise rebound characteristics might prove to be hard to obtain for individual assets. This can be alleviated by standardizing these characteristics (especially the time delay and duration of the rebound) based on type of load. While this would not be a robust solution, it could prove to be sufficient and practical.

The approach of extending what is considered to be the activation period, and thereby the timespan where the aggregator has balance responsibility over the flexible consumer/asset, could however be considered to be unfair towards the aggregator, as it removes some of the balance responsibility the supplier would normally have and might lead to the aggregator being responsible also for parts of the naturally occurring deviations from the baseline. However, in general this is a part of the wider discussion on how to divide the balance responsibility between the independent aggregator and the supplier.

The second option has some of the same caveats as the first one. Particularly, to compensate the supplier/its BRP for issues caused by the rebound effect, it should be possible to clearly distinguish the naturally occurring imbalances and those caused by the rebound effect. On the other hand, if a national transfer price methodology is established, some rebound considerations can be included there in a generalized capacity. This, however, if the same methodology is applied to all types of DR assets, would lead to socialization of the rebound costs among all DR assets, including those without rebound. On the one hand, such a generalization is welcome as it would remove the need to perform extensive and hard-to-verify calculations for individual assets. On the other hand, it would not be fair towards non-rebounding DR participants. Either way, to justify the inclusion of the rebound effect in the calculation methodology of the transfer price, it is necessary to establish the extent to which the rebound effect might cause issues to the suppliers. An example of such an analysis is provided in the later sections of this paper.

The third option is the easiest in terms of implementation. However, an undesirable effect might be achieved if the rebound effect does cause notable negative issues to particular suppliers/their BRPs. By informing the supplier of impending rebound after DR activation, an opportunity is given to it to prepare for and somewhat rectify the situation, reducing negative impacts on it. Ideally, the responsibility of this information exchange should not be put on the aggregators, but rather to a centralized data exchange entity, e.g., such as the Flexibility Register [11]. Nevertheless, also here for such data exchange to take place the rebound characteristics have to be known in advance.

Alternatively, the responsibility for the rebound effect could be assigned to the consumer whose assets have rebound characteristics (instead of the aggregator) and any corresponding financial transactions could be organized between the consumer and its supplier [4]. However, such an approach is unlikely since it would reduce the attractiveness for consumers to engage in explicit DR via aggregators and thereby go against the principle of promoting active consumer participation in electricity markets. It is also a questionable option as it could potentially give means to suppliers to discriminate against consumers who have contracted with independent aggregators (e.g., by renegotiating supply contract terms to also consider the rebound effect), which is not in line with the Electricity Directive [1], which prohibits such discrimination.

III. Financial Impact of the Rebound Effect

A. *Methodology*

The financial impact assessment methodology used in this study is adapted from [7], where the analysis was based on the Finnish case. The main principle is fairly simple – the cash flows related to DR activation for power system balancing and the subsequent rebound effect are calculated for the involved actors. Unlike in [7], we also calculate the impacts for down-regulation, i.e., consumption increase DR. The cash flows concerned are summarized in Table I, where direct expenses are marked in red, but income – in green. In case of down-regulation, the settlement model is assumed to be exactly inverse to the up-regulation case (i.e., the consumer pays for the increased metered consumption to its supplier as usual, but the supplier then compensates to aggregator by the same transfer price as in the up-regulation case).

TABLE I. Assessed Cash Flows

	Up-regulation (consumption reduction)		**Down-regulation (consumption increase)**	
	Aggregator	***Supplier***	***Aggregator***	***Supplier***
Activation time	+bal.market –compens.	–procur. +compens.	–bal.market +compens.	+tariff –compens.
Rebound time		+tariff –imbalance		–procur. +imbalance

In this study, the calculations are made for the Latvian case using the actual historical hourly price data from 2018. We assume an independent aggregator participation in the Common Baltic Balancing Market (CoBA), where the mFRR service is traded. Thereby, the input time series (in hourly resolution) are the CoBA balancing market prices [12], the Nord Pool day-ahead market price in the Latvian bidding area [13] and the imbalance prices as set by the Latvian transmission system operator [12].

A worst-case scenario from the supplier's point of view is assessed, i.e., full exposure to imbalance prices during the rebound time – no ability to procure intraday, no foresight of impending rebound. Other important assumptions and simplifications:

- The amount of activated DR is always 1 MWh/h;
- The compensation payment (ToE) price is equal to the day-ahead price and it is only applied for the DR activation, not rebound;
- The supplier procures the energy it intends to sell to consumers at the day-ahead price;
- In case of procured energy, which cannot be sold due to DR activation or rebound, the expanse to the supplier is the procurement cost and not the missed income (i.e., tariff);
- DR for up-regulation is activated if the balancing price exceeds the day-ahead price; for down-regulation – if the balancing price is below the day-ahead price;
- Rebound energy is equal to the DR energy and the effect occurs 1–6 hours after the activation;
- The do-nothing approach (the third option) is assessed, whereby the rebound effect does not financially impact the aggregator.
- The supply tariff for consumer-supplier settlement is based on the pricing of a particular popular retailer in Latvia. We consider two tariffs – a fixed one set at 58.64 €/MWh and a dynamic one, where the retailer premium to the day-ahead price is 4.66 €/MWh.

B. *Results*

Table II summarizes the sum annual cash flows related to the independent aggregator for up-regulation during DR activation hours. It is assumed a 1 MWh/h DR was activated 3057 times. The supplier's net position for this is neutral, because the assumed procurement costs and the income from compensation (Table I) are both set at the day-ahead price level. It can be seen that due to the compensation payment, the aggregator keeps only 34.42% of the income from up-regulation in the balancing market. Per unit of DR energy, the income from balancing market is 79.64 €/MWh, the compensation is 52.23 €/MWh and aggregator net position is 27.41 €/MWh. In practice, the aggregator must also be able to share its net benefit to the aggregated consumers in order to incentivize them to participate in the DR program.

TABLE II. AGGREGATOR ANNUAL CASH FLOWS (UP-REGULATION)

Income from balancing market, €	Compensation to supplier, €	Aggregator net position, €	Share from the income from balancing
243 452.28	159 664.11	83 788.17	34.42%

In Table III, the annual effects on the Supplier caused by the rebound effect following DR activation for up-regulation are summarized, based on different time delays of the rebound effect (1 hour delay means the next hour after DR). Notably, in all the cases the imbalance costs in total exceed the income from the additional energy sold both with fixed and dynamic tariff. Furthermore, if the consumers have dynamic tariff, the net position of the supplier is slightly worse. It is also possible to express these indicators per MWh of DR energy activated during the whole year (Figure 3). The net effect of the rebound varies from –3.46 to –19.90 €/MWh. interestingly, the later the rebound effect occurs, the less negative impact is has on the supplier.

TABLE III. SUPPLIER ANNUAL CASH FLOWS (UP-REGULATION REB.)

Reb. delay	Imbalance costs, €	Income from consumers, €		Supplier net position, €	
		fixed tar.	*dynamic tar.*	*fixed tar.*	*dynamic tar.*
1 h	236 057.96	179 262.48	175 225.76	–56 795.48	–60 832.20
2 h	221 297.47	179 262.48	175 719.18	–42 034.99	–45 578.29
3 h	210 704.29	179 262.48	175 309.72	–31 441.81	–35 394.57
4 h	203 145.19	179 262.48	174 742.40	–23 882.71	–28 402.79
5 h	195 990.86	179 262.48	173 848.80	–16 728.38	–22 142.06
6 h	189 852.93	179 262.48	172 937.17	–10 590.45	–16 915.76

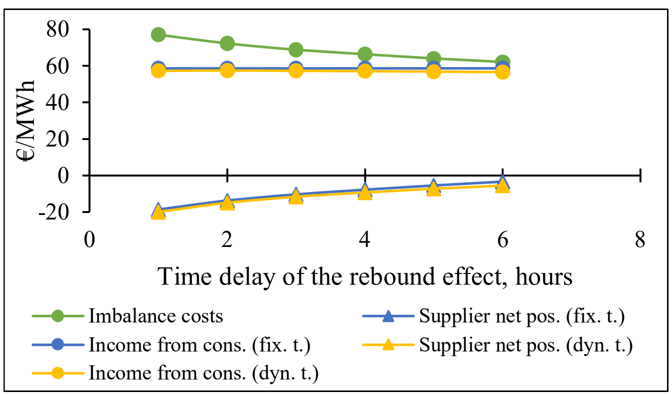

Figure 3. Supplier per-MWh cash flows (up-regulation rebound)

We can similarly summarize the results for the down-regulation (i.e., consumption increase DR) as well. The sum annual results of the activation time are summarized in Table IV. It is assumed DR was activated 3251 times.

The supplier in this case earns the difference between the tariff and the day-ahead price for the extra energy consumed during DR activation. On the other hand, the aggregator receives the difference between day-ahead price and down-regulation price. A note should be made, however, that the aggregator should share in its revenue with the aggregated consumers, otherwise they do not have any incentive to participate in such a DR scheme.

TABLE IV. AGGREGATOR & SUPPLIER ANNUAL CASH FLOWS (DOWN-REGULATION)

Aggregator expense for bal. energy, €	Compensation to aggregator, €	Aggr. net position, €	Supplier net position, €	
			fixed tariff	*dynamic tariff*
91 593.49	161 343.86	69 750.37	29 294.78	15 149.66

Per unit of DR energy basis, the aggregator's net position is 21.46 €/MWh. whereas the supplier's net position is 4.66–9.01 €/MWh depending on the type of consumer tariff. Initially, it seems that such DR participation is power system down-regulation with these settlement rules is beneficial to both the aggregator and the supplier, however also here we must take into account the effects caused by the subsequent consumption reduction due to the rebound effect (Table V). The rebound effect's negative financial impact on the supplier far exceeds the additional income obtained during the activation (down-regulation) time. However, similarly to the up-regulation case, the later the rebound occurs, the less negative impact it has.

TABLE V. SUPPLIER ANNUAL CASH FLOWS (DOWN-REGULATION REB.)

Reb. delay	Day-ahead procurement costs, €	Income from positive imbalance, €	Supplier net position, €
1 h	160 583.03	82 966.90	–77 616.13
2 h	159 562.39	94 487.20	–65 075.19
3 h	158 323.36	102 200.76	–56 122.60
4 h	156 707.31	107 019.04	–49 688.27
5 h	155 277.47	112 068.39	–43 209.08
6 h	154 093.04	115 519.26	–38 573.78

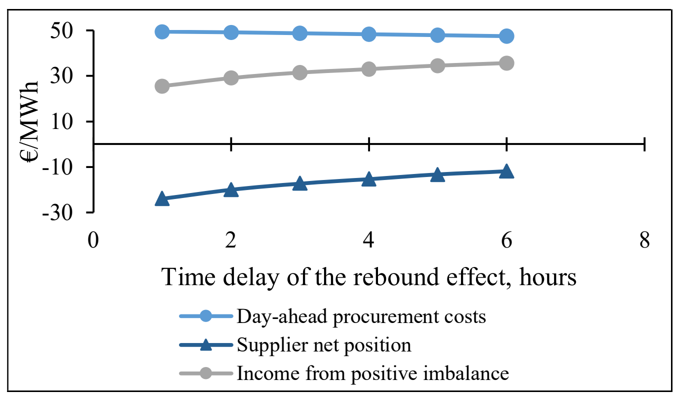

Figure 4. Supplier per-MWh cash flows (down-regulation rebound)

The cash flows of the supplier during the rebound effect after down-regulation can also be expressed on the basis of DR energy served (Figure 4). In this case, the net effect on the supplier varies from –11.87 €/MWh to –23.87 €/MWh, depending on the time delay of the rebound effect.

These results show that if not accounted for during ToE and aggregator-supplier settlement, the rebound effect does have the capacity to bring notable negative effect to the suppliers involved. Moreover, this is true for DR activations in both power system up-regulation and down-regulation.

If the aggregator itself carried imbalance responsibility for the rebound effect (the first option) the business case of independent aggregation for power system regulation would be negated (if we, for instance, compare the imbalance costs in Table III to aggregator's net position in Table II). Even if there was no aggregator-supplier ToE compensation, the business case would be nearly negated as the income from the balancing market would only slightly exceed the imbalance costs of rebound. If the rebound effect was included in the ToE price calculation for a more fair and sophisticated approach (the second option), by e.g., compensating only the net negative impact on the supplier, it is evident the aggregator might be able to maintain its business case, but its profitability would nevertheless be reduced. Moreover, a fairly complicated, yet transparent and verifiable procedure would need to be in place to indeed estimate the actual net effect the suppliers have because of post-DR rebounding.

On the other hand, the results presented in this study do portray a worst-case scenario, whereby there always is rebound and it is always in the same amount as the DR energy. Another extreme scenario is conceivable, whereby there never is any rebound effect. It follows that in reality the actual rebound characteristics and the resulting negative impact on the supplier would fall somewhere in between these extremes, and thereby the net effects calculated here only provide the upper bound as far as the up-regulation case is concerned. For the down-regulation case, however, lack of rebound is less likely, since otherwise the consumer's total expenses will have increased due to more total energy consumed. Such down-regulation is perhaps conceivable in case of negative prices and if the aggregator is willing to share a notable proportion of its revenue.

Nevertheless, ultimately, the rebound effect issue is complicated and hard to analyze analytically. Furthermore, the actual impact of the rebound effect on the suppliers heavily depends on the share of customers contracted to independent aggregators and the total portfolio of the supplier, i.e., if there are relatively few flexible customers engaged with third-party aggregators, the impact on the portfolio as a whole will also be miniscule. This is a reason why the Nordic Energy Regulator Association NordREG proposes in its recommendations to postpone a decision on if and how to include the effect in settlement models after an initial independent aggregator framework is already in operation [11]. This would allow to assess the actual issues induced by the effect on suppliers.

Conclusions

If the rebound effect is not addressed in independent aggregator frameworks, there is a risk it could cause negative financial impact on the suppliers the customers of which have contracted with independent aggregators. In a worst-case scenario where demand response only takes form as load shifting (i.e., there is always full rebound), the costs incurred to the impacted suppliers are significant in absolute terms. However, in relative terms, the impact depends on the proportion of such customers the supplier has in its portfolio. Thereby the negative impact could be more pronounced on smaller and emerging suppliers.

On the other hand, if the rebound effect is either accounted for in the compensation mechanism or if the balance responsibility for it is assigned to the aggregator, in the worst-case scenario, the independent aggregator business case is nearly negated. This would be at odds with the current European goal of more actively involving consumers in the provision of ancillary services. Conversely, it could incentivize aggregators to engage only with non-rebounding assets, but that would not utilize all of the flexibility available on the demand-side.

However, the financial impacts of the rebound effect identified is this study are likely overestimations due to the underlying assumptions. In practice, there is a lot of uncertainty regarding this topic since it depends on many factors, especially on the composition of assets in both the aggregator and supplier portfolios. Furthermore, with sufficient data exchange it should be possible to at least partially warn suppliers of expectable rebounds to allow them mitigating the negative impacts.

A practically feasible recommendation is to initially develop independent aggregator frameworks without devising specific settlement mechanisms particularly for the rebound effect. However, the door should be left open for possible introduction of such mechanisms if, in practice, they turn out to be necessary, but this can be assessed decisively only if data concerning actual DR activations and related rebounds is compiled and analyzed.

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