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Application of distinct demand response program during the ramping and sustained response period

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Abstract

The environmental concerns around energy, namely electricity, have driven attention to innovative approaches to fostering consumers participation in the whole energy system management. Accordingly, the concept of demand response provides incentives and signals no consumers to change the normal consumption patterns to increase the use of renewables, for example. The problem is that such response of consumers has a large amount of uncertainty. This paper proposes a methodology in which different demand response programs are activated and deactivated during an event to cover the demand response deviations from the target. Even after achieving the response target, if the actual response of consumers is reduced to a critical level, additional programs are activated. The proposed approach considers consumers participating in an aggregate way, supported by an aggregator. The case study in this paper accommodates three demand response programs, showing how different consumers are activated and remunerated for the provision of consumption reduction. It has been seen that the proposed methodology is flexible as desired to accommodate the uncertainty of consumers' responses.

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Keywords: Aggregation; Demand response; Uncertainty

1. Introduction

Demand Response (DR) is related to a set of incentives or electricity price signals to the consumers to induce a change in the normal consumption pattern due to economic or technical reasons. It has been proven to be very effective [1]. Several barriers are, however, identified in Faria and Vale [2]. Adequate strategies are therefore required to optimize the use of DR and deal with the uncertainty of the consumers' response [3]. Price elasticity of demand parameter is a well-known approach to model consumers' response to changes in prices. However, this parameter has a linear nature that does not reflect consumers' contextual changes [4]. Aggregation of consumers providing

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DR is another way to handle uncertainty. An aggregator collects small amounts of DR, delivering it as a whole to the electricity market, to the distribution system operator, or another player [5].

During the DR event, a specific moment when the DR program is activated, consumers are called to provide demand reduction. According to [6], the aggregation concept can continuously adapt to the different consumers' responses during the event. In fact, in Abrishambaf et al. [7], the authors proposed a methodology to handle the activation of different DR programs during a DR event to collect the total amount of response required in real-time. The focus was given to the ramping period, where the consumers provide an actual response before the reduction deadline, so the required amount is fulfilled at this last moment. However, the sustained response period was not adequately addressed.

In the present paper, the authors propose a methodology where:

- the consumers are continuously managed during the sustained response period;
- when a consumer or set of consumers are not provided the demand reduction anymore, another consumer is called
- alternatively, as proposed, an additional program is activated.

After this introduction, Section 2 presents the proposed model, Section 3 provides the case study and results, and Section 4 gives the main conclusions of the work.

2. Methodology

The proposed methodology is devoted to managing DR programs by an aggregator in the context of a request by a network operator or an electricity market operator. The aggregator will request medium and small size consumers and producers to reduce consumption, as illustrated in Fig. 1. Demand response programs will be activated, as illustrated in Fig. 2.

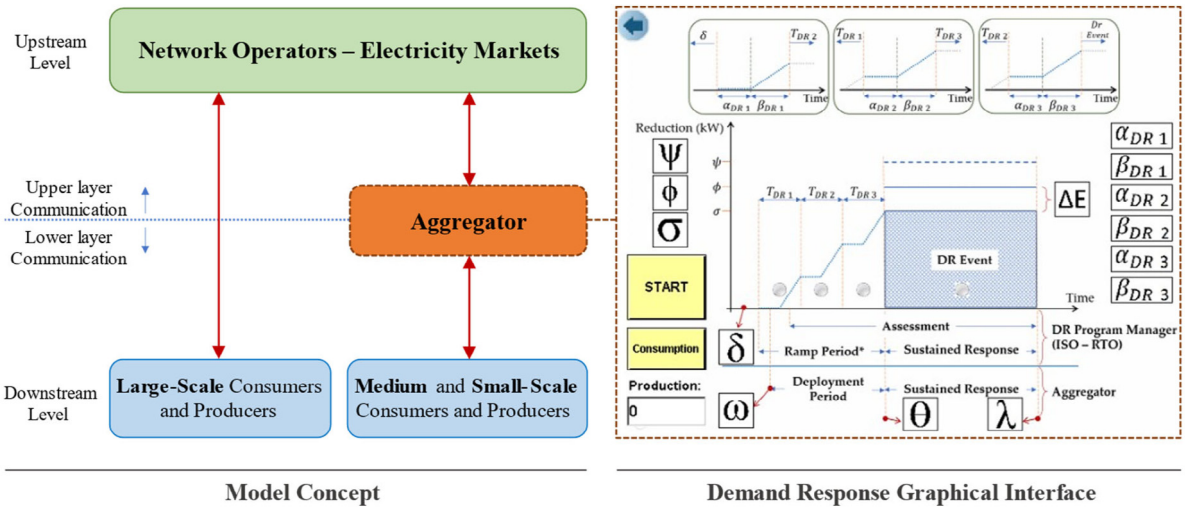

Fig. 1. Overview of the system.

As shown on the right side of Fig. 1, DR programs are activated during both the ramping and the sustained response periods, aiming for a certain overall reduction target. Finally, as shown on the left side of Fig. 1, the aggregator can use the proposed methodology to collect the small amounts of DR and deliver it to the electricity market, which is the final target of the aggregation process.

The main contribution of the present paper relies on the use of DR programs on the sustained response period. As seen in Fig. 1, a certain response from consumers is expected during the DR event, in which the consumers will be remunerated for the consumption reduction provision. According to Fig. 2, DR1 and DR2 programs are used to reach the desired reduction during the ramping period. Then, during the DR event, the DR3 program is activated to overcome situations in which the actual response is lower than the required level. Adequate remuneration levels are defined for each program depending on whether they are activated during the ramping or during the event. The use of the proposed methodology is illustrated in Section 3.

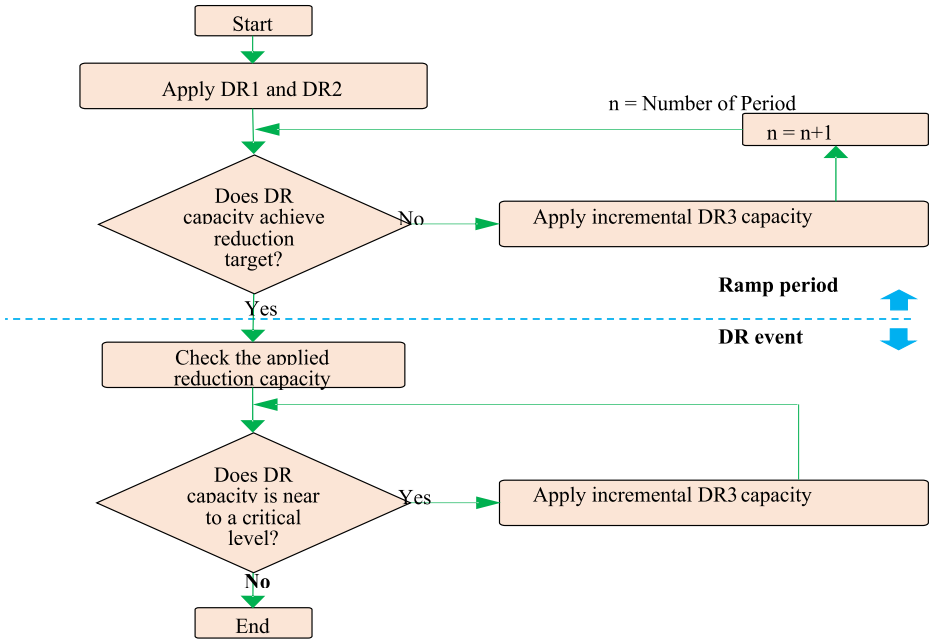

Fig. 2. Proposed demand response programs activation.

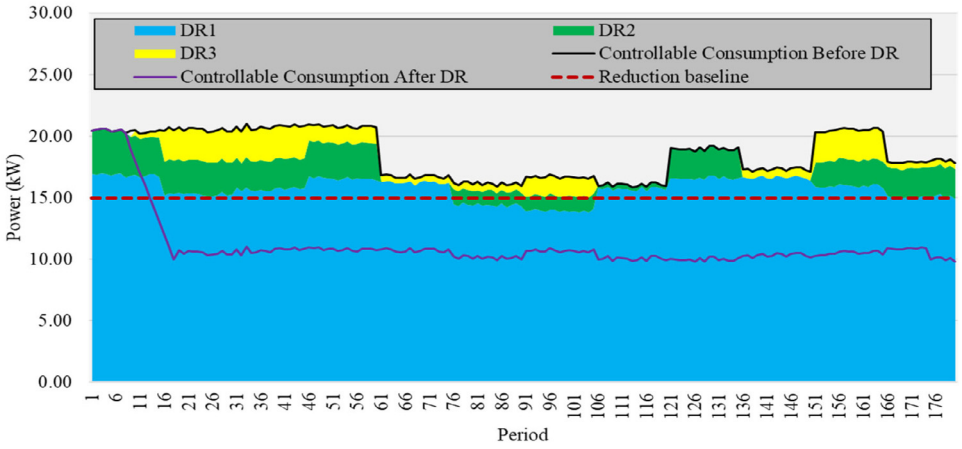

Fig. 3. Available DR program capacities and reduction baseline.

3. Case study

The case study in this paper is based on the data [8]. As shown in Fig. 3, facing a reduction baseline, which represents the amount of consumption reduction during the DR event, equal to 15 kW, we can have different options for demand reduction. The latter are the three DR programs implemented, namely DR1, DR2, and DR3, which have different capacities.

The above-mentioned DR programs were represented as the total amount of each program. In fact, regarding the DR3 program, five distinct consumers have been considered, as shown in Fig. 4.

The five consumers in the DR3 program have different consumption reduction capacities according to Fig. 4. in that way, depending on the moment of the DR event, different consumers will be offering distinct amounts to follow the target reduction baseline.

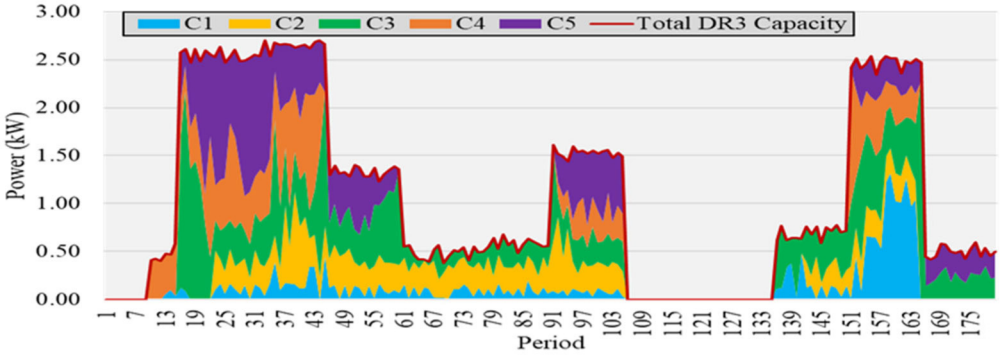

Fig. 4. Consumers in the DR3 program.

Table 1. DR remuneration in distinct periods [m.u.].

Period	DR1	DR2	DR3				
			C1	C2	C3	C4	C5
0–30	0.04	0.06	0.07	0.10	0.09	0.11	0.12
31–60	0.04	0.06	0.07	0.10	0.09	0.11	0.12
61–90	0.04	0.08	0.12	0.10	0.12	0.11	0.12
91–120	0.07	0.08	0.12	0.10	0.12	0.11	0.12
121–150	0.07	0.08	0.12	0.10	0.09	0.11	0.08
151–180	0.07	0.08	0.12	0.08	0.09	0.11	0.08

Regarding the remuneration of the participation in the DR event, for each program and each consumer in the DR3 program, different prices are paid per kWh delivered, according to the period of the day, as seen in Table 1.

Different DR programs and consumers will be activated according to the distinct remuneration prices, depending on the DR event time, using the proposed methodology.

4. Results and discussion

The results obtained using the proposed methodology applied to the case study defined in Section 3 are presented in Figs. 5 and 6.

As shown in Fig. 5, there are two critical periods where the use of DR1 and DR2 programs is not enough to keep the consumption reduction within the acceptable range, namely periods 28 to 45 and 152 to 165. The bottom picture of Fig. 5 shows the specific consumers activated in the DR3 program. Comparing the two DR event periods for the DR3 program, one can see that consumer C5 is very active in the first DR event but with a lower contribution in the second DR event. Regarding consumer C1, it is very active in the second DR event but less active in the first DR event. Such differences are caused by the specific amount of reduction available in each consumer in each period, seen in Fig. 4, and the respective remuneration prices, seen in Table 1.

Regarding the remuneration of distinct programs and consumers, as presented in Fig. 6, one can see the cumulative remuneration achieved along the day. As expected, despite the DR1 program is cheaper, due to the higher amount of consumption reduction provided, this program has the highest remuneration. Regarding the DR3 program, as seen in the bottom of Fig. 6, the increment of remuneration can be seen in the time of the two DR events. Consumer C1 had low remuneration in the first DR event, and higher remuneration came in the second DR event. At the end of the day, each of the five consumers in the DR3 program had similar remuneration, with consumer C2 having the lowest remuneration. This consumer is not too expensive, but the available amount of consumption reduction is relatively low.

Regarding the quantitative remuneration, the consumer with greater remuneration is consumer C5, with around 0.28 euro of remuneration. Consumer C1 reaches a similar amount. However, in the latter, such remuneration is only obtained in the last periods, while consumer C5 obtains remuneration in earlier periods.

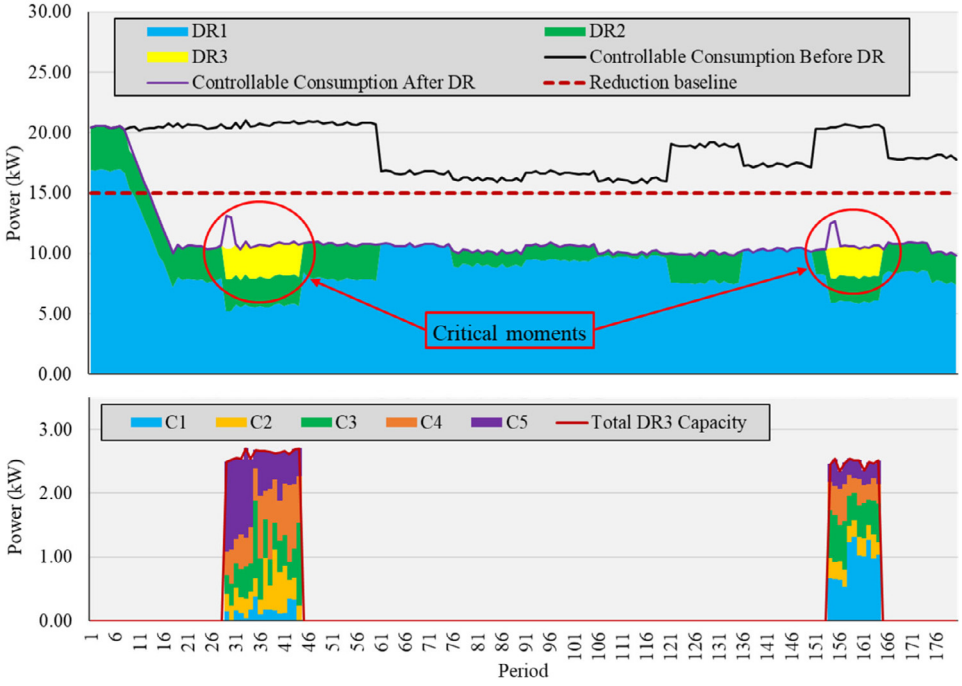

Fig. 5. Activation of distinct DR programs and consumers in each DR event.

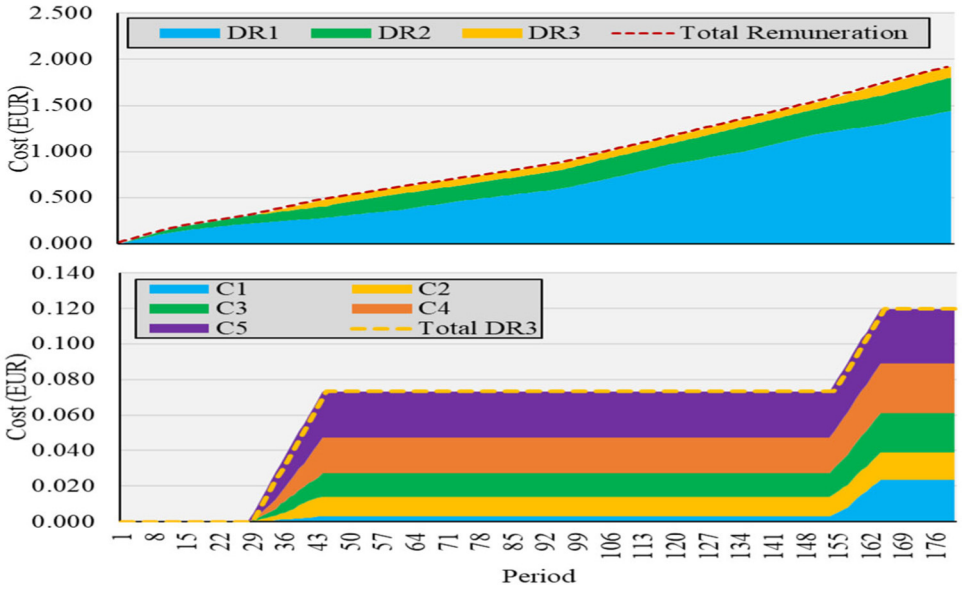

Fig. 6. Remuneration of distinct programs.

5. Conclusion

Demand response programs are a valuable resource in the operation of power and energy systems, bringing benefits to consumers, the network operator, and the electricity market. Other players like an aggregator can have a great role in DR programs. The proposed methodology aimed to provide a way to address the uncertainty of consumers' responses in real-time to DR events. When the target reduction baseline deviation is critical, five

distinct consumers are activated as needed, which belong to the same DR program. The remaining two programs are activated as blocks without the knowledge of individual consumers participating. It can be concluded that by selecting the available consumers in real-time, it is possible to overcome the uncertainty of response in DR programs treated as blocks during the sustained response period or the DR event. This implies that adequate remuneration must be provided and handled as dependent on the period of the day and other context variables.

CRediT authorship contribution statement

Pedro Faria: Data curation, Formal analysis, Investigation, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. **Zita Vale:** Conceptualization, Data curation, Funding acquisition, Methodology, Project administration, Resources, Supervision, Validation, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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