VALUATION OF CONSUMPTION FLEXIBILITIES IN DISTRIBUTION SYSTEM PLANNING

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ABSTRACT

The methodology described in this article aims at estimating to what extent the grid functioning and primary substation investment costs can be reduced when using innovative levers such as demand response (DR) flexibilities.

This methodology can be applied for two different purposes:

a. *it can screen a set of substations in order to identify those for which DR flexibilities can be economically justified;*
b. *it can provide a detailed analysis of DR flexibilities on a specific substation.*

INTRODUCTION

Investment framework in France

ERDF operates the distribution system so as to minimise the functioning costs of the network. As a result ERDF bases **the decision of investing on the French distribution system on the comparison of the annualised cost of investing and the probabilistic benefits that the investment brings** (e.g. in terms of losses and Expected Energy Not Served – EENS – reduction) [1].

Considering primary substation (HV/MV) reinforcements, benefits in terms of EENS reduction are calculated probabilistically for different levels of charge and for different types of N-1 situation. The comparison of the net present costs of different reinforcement strategies guarantees that the best strategy is selected and that the reinforcement is made at the optimal date.

Not all the existing DSOs use probabilistic cost benefits criteria. For example, some DSOs justify their investment based on deterministic criteria (e.g. the investment trigger may be a power threshold). This article tackles the topic of assessing the value of demand response (DR) flexibilities exclusively within the French investment framework.

Scope

This methodology is designed specifically for assessing the value of demand response flexibilities for the distribution grid. Throughout this article, the demand response flexibilities are used exclusively in order to postpone investments on HV/MV transformers.

Objective

This methodology aims at assessing the total value that the flexibilities represent for the distribution system assuming a priori that they have zero cost. As a result, it does not allow deriving directly the economical benefits stemming from the use of DR flexibilities on the distribution grid. However, based on the results of this methodology, it is possible to estimate how the functioning costs of the grid would decrease, for a given power capacity and considering that the flexibilities are used as much as possible.

N.B.: This strategy of making use of flexibilities does not optimise their unit value.

METHODOLOGY

Main principles

It is considered that the use of flexibilities can reduce the EENS. As a result depending on both, the available volume of flexibilities and the mobilisation time, the benefits that the investment would bring are reduced. Thus, as shown in **Figure 1**, the optimal investment date can be postponed.

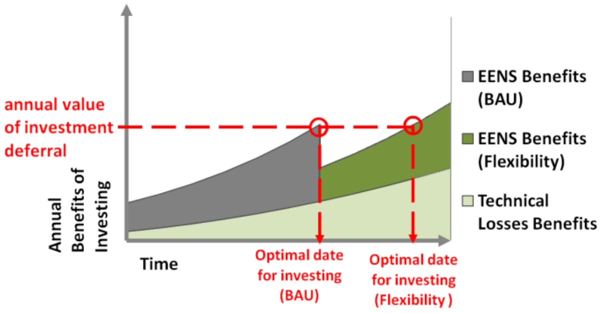


Figure 1: Determination of the optimal date for investing (BAU and flexibility strategies)

Estimating the reduction of EENS is the critical point of this methodology as this estimation basically assesses the usefulness of the demand response flexibilities for the distribution grid. This estimation is carried out under different scenarios. Each scenario consists in crossing one level of charge (from off-peak to peak) with one state of the distribution grid (normal situation, different types of N-1 situation).

On the one hand, under normal operating conditions, DR flexibilities can reduce the demand peaks, thus avoiding exceeding the thermal constraint thresholds of the transformers.

On the other hand, when a fault occurs in the primary substation (HV supply, HV/MV transformers, MV busbar), the DR can reduce the power not served during each step of the grid recovery. **Figure 2** illustrates an example of the use case of DR flexibilities.

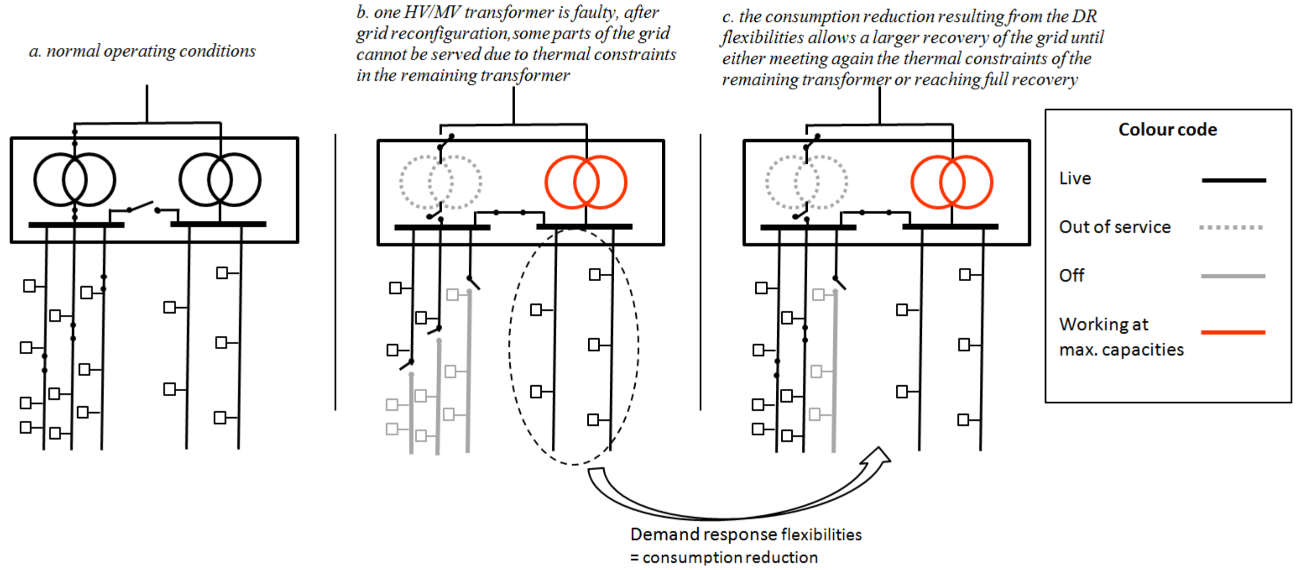


Figure 2: Illustration of the demand response flexibilities use case for the distribution grid

Demand response model

Characteristics of the demand response flexibilities

The DR flexibilities are characterised with two parameters: the power capacity of flexibilities (in kW) and their activation delay (period of time between the solicitation and the physical effect on the network).

This methodology considers that the available flexibilities answer exactly to the network need in terms of shape. In other words, any negative side effects that can be associated with the use of DR flexibilities (e.g. payback effect) are not taken into consideration: it is considered that flexibility providers will manage to supply such “ideal” flexibilities.

Implementation assumptions

The DR flexibilities are assumed to be distributed over the distribution grid, proportionally to the consumption of the MV/LV transformers and the MV consumers.

It is assumed that DR flexibilities are not likely to modify significantly the technical losses on the grid. As a result, the direct effects of flexibilities on the technical losses have not been estimated.

For simplicity purposes, the methodology does not take into account the actual location of the breaking equipments (remotely controlled or not) on the grid. Thus, it does not consider the threshold effects of these equipments on the efficiency of DR in reducing the energy not supplied.

It is also considered that the DR flexibilities are absolutely reliable and that each consumption shedding reduces the energy not served from an equal amount.

Finally, it is assumed that the consumption forecasts are totally certain when DR flexibilities are activated (i.e. only the necessary quantity of flexibilities is activated).

These assumptions corresponding to ideal operational conditions will tend to overestimate the resulting maximum value of the flexibilities.

Selected strategies

Three main strategies are studied in this methodology. The BAU (Business as usual) strategy considers the current grid planning rules. In the flexibility strategy, demand response flexibilities are used to postpone, for some time, an investment. Lastly, in the do-nothing strategy, no investment or flexibilities are considered on the grid throughout the study period.

Input data

In order to apply this methodology, several input data are required among which are notably:
- the consumption forecasts over the study period (including consumption growth);
- the discount rate; and
- the costs related to energy not served;

Possible uses of the methodology

Screening a set of substations

The methodology can be used for screening a set of substations so as to identify the substations for which the value of DR flexibilities is not negligible. Basically, the methodology helps to compare the grid functioning costs of the do-nothing and the flexibility strategies.

As the do-nothing strategy is not optimal for every substation, it may overestimate the value of the flexibilities. However, based on this result, it is possible to screen for the substations whose overestimation is low over the study period: these substations are unlikely to provide sufficient value to justify the use of flexibilities and will not be studied further.

Detailed analysis

The methodology can also be used in order to focus on a specific substation. In this case, its purpose is to determine precisely the value of the flexibilities by comparing the grid functioning cost in the BAU strategy and in the flexibility strategy that maximize their usage (even if their marginal value decreases). It enables to determine how the functioning cost decreases depending on the characteristics of the flexibilities.

The detailed analysis application of the methodology and the results that it can provide are described further in the following illustrated case.

ILLUSTRATED CASE

Context

This illustrated case focuses on a single substation that was selected especially for the application of the detailed analysis of the methodology. This substation is composed of two 36 MVA HV/MV transformers.

The investment in a third 36 MVA transformer is under study based on the benefits that it would bring in terms of EENS reduction under fault conditions.

Input data

Consumption growth

The growth rate that was considered is based on past consumption measurements (it ranged between 1% and 2% p.a.).

Consumption scenarios

Numerous consumption scenarios were taken into account in order to represent the variability of the consumptions from one year to another over the study period (as the French electric consumption is very thermo-sensitive, it depends greatly on the weather scenarios). This involved the statistical processing of a large amount of data using a specific processing technique [2].

Discount rate

Conformingly to the French public investment guidelines, a discount rate of 4.5% was selected [3].

Results

N.B.: At the time of writing, the economic value of the flexibilities in this case study cannot be disclosed.

The results below are calculated without considering the costs of activating the flexibilities. A constant power capacity of flexibilities is assumed to be used each year as long as the investment deferral is justified economically.

Annual value of demand response flexibilities

Thanks to the above described methodology, it is possible to estimate the average yearly value of the flexibilities (expressed in €/kW/year) depending on the power capacity of the available flexibilities.

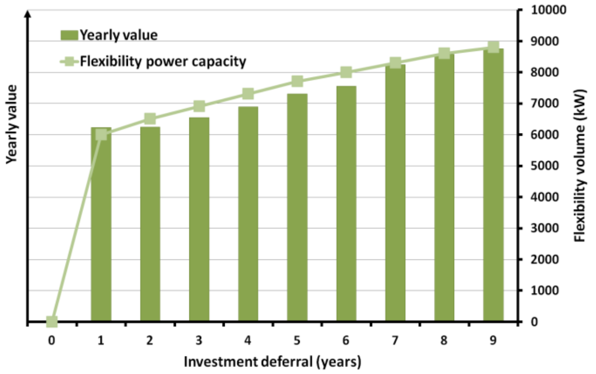


Figure 3: DR yearly value

Figure 3 shows that, in this case, a large volume of flexibility (6 MW) is required to defer the investment of a single year but then, postponing of an extra year requires only a small additional volume (400 kW on average).

In this example, **as the investment is mainly justified by N-1 situations** (that do not happen frequently), each kW is activated, on average, approximately one hour each year during which the investment is postponed.

Consumption shedding

The methodology can also give some details on the volume of energy shedding required to defer the investment.

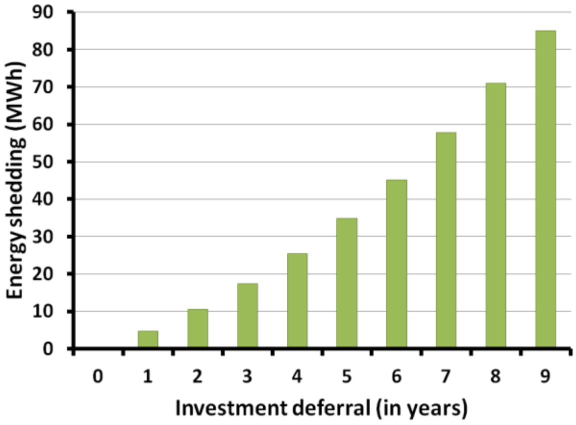
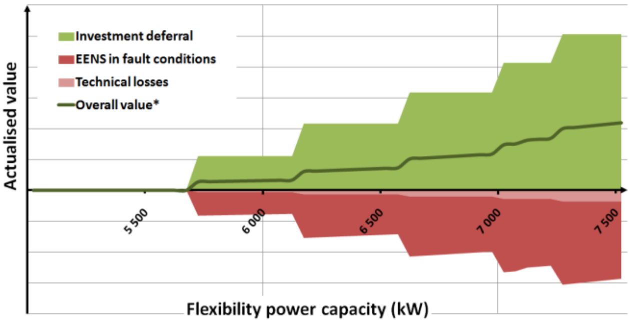


Figure 4: Volume of energy shedding required to defer the investment

As shown in **Figure 4**, in this case study, each year during which the investment is postponed requires about 5 to 15 MWh of energy shedding.

Creation and destruction of DR value

The methodology allows also identifying exactly what are the impacts of the flexibilities on the different categories (e.g. technical losses, investment costs, EENS) of the economic balance for the above described strategy of use.



green = value creation / red = value destruction
* activation delay = 30 min

Figure 5: Value structure

Figure 5 describes the impacts on the economic balance when using DR (with a 30-minute activation delay) for the illustrated case.

The results in this case study show that that the value creation (green area above the x-axis) is exclusively based on the financial benefit of postponing the investment. Among the negative impacts of the use of flexibilities to defer the investment of this case, the most important one is the increase in the cost related to EENS: in this case, the flexibilities can help to improve the quality of service to cost ratio of the grid but this would result in a slightly lower quality of service.

Overall value of the flexibilities

Lastly, the methodology can provide information on the actualised value of the flexibilities depending on their power capacity. The sensibility of the actualised value to the activation delay is also provided by this methodology.

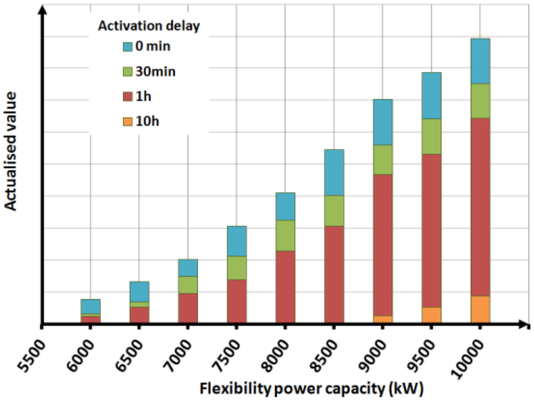


Figure 6: Actualised value of the flexibilities over the study period

Considering the context of this illustrated case, it is not surprising to observe that the flexibilities appear, for this primary substation, to be valuable exclusively when used under fault conditions.

Also **Figure 6** shows that, in this example, most of the value can be captured with flexibilities whose activation time is less than an hour.

CONCLUSIONS

The methodology described in this article allows either to screen a set of primary substations in order to identify the ones for which flexibilities can be valuable or to analyse in more details the value of DR flexibilities for a specific primary substation (the value characterisation depending on the power capacity and the activation delay of the flexibilities)

It was successfully applied to different primary substations presenting various configurations of the distribution system. At first, the initial screening of a set of substations was completed. Then it provided the detailed characteristics of the value of DR flexibilities for specific examples.

As the **Figure 6** shows it, the results depend largely on how the flexibilities are implemented. That is why, in the frame of the Smart Grid Vendée project, experiments on flexibilities are currently carried out by a consortium composed of ERDF as well as seven other public institutions and companies, including a DR aggregator. The results of these experiments will help to enrich this methodology. As a consequence, this should allow the consortium of the Smart Grid Vendée project to estimate the value of the demand response flexibilities at the scale of the project's transport and distribution system.

REFERENCES

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