FLEXIBILITIES IN GRID PLANNING: CASE STUDIES ON THE FRENCH DISTRIBUTION SYSTEM

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ABSTRACT

This article describes the application of a flexibility valuation methodology over two different grid configurations of the French distribution system.
For each of these configurations, the results as well as their sensitivity are detailed.

INTRODUCTION

Valuation of flexibilities

The methodology applied in this article aims at estimating to what extent the failure costs, the grid functioning costs and the primary substation investment costs can be reduced when using innovative levers such as demand response, storage or distributed energy resources.

It is designed specifically for assessing the value of flexibilities for the distribution grid. In this article, the flexibilities are used exclusively in order to postpone investments on HV/MV transformers. For a thorough description of the methodology, please refer to [1].

While using probabilistic socio-economic net present value to make investment decisions has been customary for decades in France, the implementation of this methodology to assess value of flexibilities with this level of detail was conceived in the frame of the Smart Grid Vendée project.

Extrapolation of the results

The results of the case studies are very specific to the grids on which the valuation methodology was applied. They depend largely on local grid configurations and local consumption patterns. As a consequence, these results can in no way be extrapolated.

Selected case studies

Two different case studies were selected. They provide two different grid configurations and consumption patterns. In both cases an investment in the primary substation is justified.

Although these case studies represent examples of grid configuration for which investments are under study, their results cannot be extrapolated to similar grid configurations as they rely largely on the consumption patterns of the studied grids.

FLEXIBILITIES IMPLEMENTATION

Two different sets of assumption have been designed so as to illustrate a scenario where the flexibilities are optimally distributed (thereafter referred to as “maximal value scenario”) and a scenario where the flexibilities are homogeneously distributed over the distribution grid (rather pessimistic scenario thereafter referred to “homogeneous distribution scenario”).

These two scenarios make it possible to assess the sensitivity of the valuation to the location of the flexibilities on the grid.

Maximal value scenario

Under this scenario, the overall power capacity of the flexibilities is set beforehand. It is then considered that the whole power capacity can contribute to reduce the expected energy not served (EENS) in case of grid failure. As a result, the constraints associated with the location of the flexibilities are not considered in this scenario.

Although this scenario would be difficult to operate practically, it allows to describe the value of the flexibilities and the associated requirements in the best case scenario.

Homogeneous distribution scenario

In this scenario, the power capacity of the flexibilities is defined at first. When a grid failure occurs, it is then considered that the flexibilities are spread across the power loads proportionally to their consumption levels.

As a result of this assumption, when a grid failure happens, it is likely that some of the flexibilities will not contribute to the grid recovery as they are not suitably located.

This scenario results in using inefficiently the flexibilities and thus provides information on the valuation and the characteristics of the flexibilities in a suboptimal scenario.

Other assumptions

Unless contrary stated, the results of these case studies have been calculated with:

- an activation delay of 40 minutes[1];
- a discount rate of 4.5%.

Lastly, the implementation cost of the flexibilities is not taken into account in the methodology. As a consequence, the results of the methodology provide information on the maximal value that can be captured.

CASE STUDY #1

Description of the case study

This first case study concerns a distribution grid which is already fed by two HV/MV 36 MVA transformers.
The addition of a third HV/MV 36 MVA transformer is under study as pre-studies show that in case of grid failure, power outages are likely to happen in several parts of this grid (including large industrial loads). Therefore it could be more beneficial to invest in a third transformer rather than to risk these power outages.

The study being carrying out over a 30 year period, the investment is planned initially for the fifth year.

Characteristics of the required flexibilities

Minimum requirements for an investment deferral
The results show that the minimum power capacity[2] required to postpone the investment of one year reaches **6,500kW** for the maximum value scenario and **14,000kW** for the homogeneous distribution scenario[3].

Considering the volume of flexibility associated with the investment deferral, it appears that the flexibilities would on average be activated for about one hour per year. However this figure represents an average taking into account both the various types of incidents that could happen on the grid and the climatic variations. Further details on the activation durations for this case study are detailed below.

Valuation of the flexibilities

Annual value

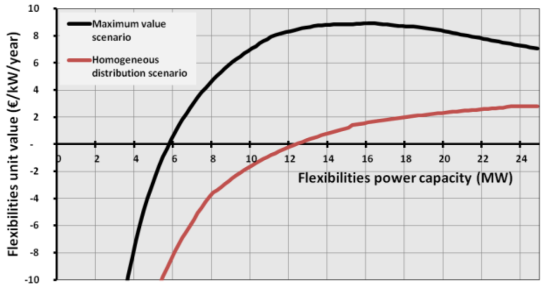

Figure 1: Flexibilities unit value for an investment deferral of a year

Figure 1 shows that in this example, the maximum unit value of the flexibilities reaches 3€/kW/year or 9€/kW/year depending on the flexibility distribution scenario. This unit yearly value represents the maximum costs (including the DSO implementation costs) that could be accepted for the investment deferral to be economically viable.
Under a certain power capacity, the unit values for both scenarios are negative which means that postponing the investment with so little flexibilities would increase the functioning costs of the distribution grid (even if the flexibility implementation and activation had no cost).

For both scenarios, the shape of the value curve shows that each additional kW of flexibility is slightly less useful than the previous one. This creates a peak unit value for a set power capacity that is dependent on the scenario.

Societal value and value structure
N.B.: the results described in Figure 2 are calculated considering the power capacity that maximises the unit yearly value of the flexibilities for the maximum value scenario.

Figure 2 depicts the benefits and costs of two scenarios when compared to the do-nothing scenario. These two scenarios are:

- the business as usual (BAU) scenario; and
- the maximal value scenario where the investment is postponed of a year.

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1 The activation delay includes both the decision process leading to the activation and the activation itself.
2 The minimum power capacity represents the threshold under which the service provided by the flexibilities is not sufficient to economically justify the investment deferral, as this would increase the functioning costs of the grid.
3 These power capacities represent 10 and 20 percents of the maximal consumption of this distribution grid.

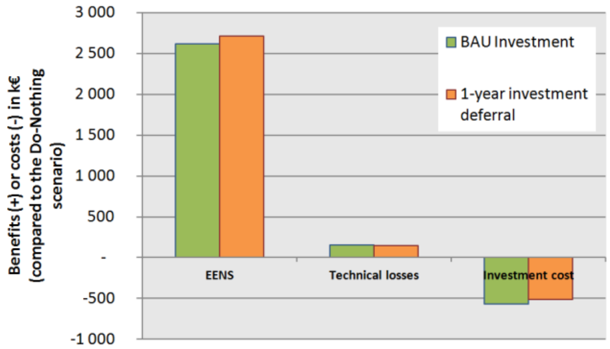

Figure 2: Comparative benefits and costs of the BAU scenario and the maximal value scenario for a one-year deferral

As shown in Figure 2, the BAU scenario and the 1-year investment deferral scenario have both similar consequences compared to the do-nothing scenario:
- they both result in lower EENS costs;
- they both result in lower technical losses costs;
- they, evidently, both result in greater investment costs.

When comparing both scenarios between each other, it appears that:
- the 1-year investment deferral scenario is less beneficial than the BAU scenario in terms of technical losses costs (€11k reduction of the benefits);
- the 1-year investment deferral scenario is more beneficial than the BAU scenario in terms of EENS costs (€99k increase of the benefits);
- the 1-year investment deferral scenario is less costly than the BAU scenario in terms of investment costs (€56k reduction of the investment costs).

Sensitivity to the activation delay

Sensitivity of the annual value to the activation delay

Figure 3 shows the variation of the maximal unit value (when the investment is postponed of one year) with the activation delay.

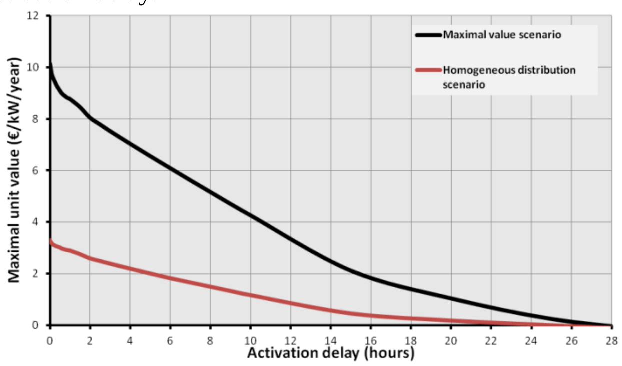

Figure 3: Sensitivity of the unit value to the activation delay

For both scenarios, the maximal unit value decreases smoothly as the activation delay grows. It appears that half the unit value cannot be captured when the activation delay exceeds 8h. Roughly no value can be captured when the activation delay exceeds one day.

As described below, the sensitivity to the activation delay depends primarily on the most critical types of incidents that can occur. Once the durations of the most stringent incidents are exceeded, the flexibilities cannot bring any value to the distribution grid.

Characteristics of the period of use

The use of flexibilities in both case studies depends on the occurrence of an incident while the electrical consumption does not allow a sufficient recovery of the loads. Thus, the use of flexibilities will depend on:
- the types of incident that can occur as well as their frequencies and durations;
- the period of the year at which the incident occurs; and
- the climatic conditions at the time[4].

Sensitivity to the consumption scenarios

In order to account for the various climatic scenarios that can happen over a single year, 245 consumption scenarios have been considered based on the weather conditions recorded over the last 30 years.
Figure 4 describes the average durations of flexibilities activations across the different scenarios.

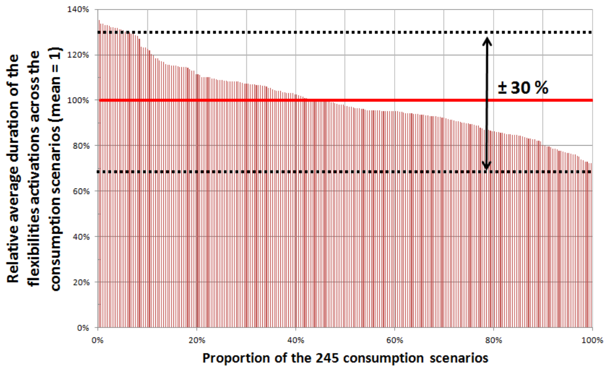

Figure 4: Description of the duration of the flexibilities activations across the different consumption scenarios

Figure 4 shows that the duration of the flexibilities activation across the scenarios is rather steady: it varies only from +/- 30% from the average estimated value.

As a consequence, it appears that the average duration of the activations is, in this case study, not very dependent upon the climatic scenario.

Periods of use

Figure 5 shows how the likeliness of activating the flexibilities is distributed over the year.

4 The electrical consumption in France is largely temperature-dependent. As a result, it is generally higher during winter months and can vary much from a week to another.

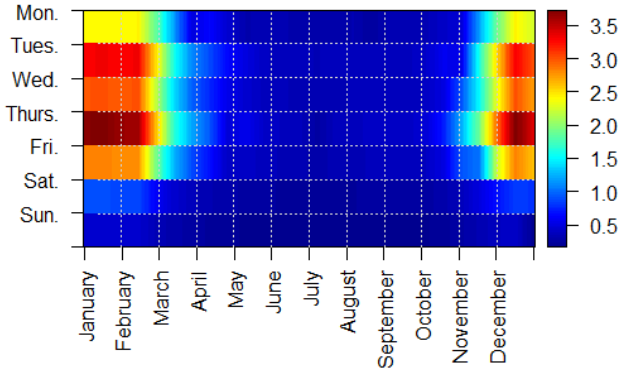

Figure 5: Statistical need for flexibilities over the year (average for 245 climatic scenarios / mean=1)

As shown in Figure 5, the use of flexibilities is more likely to take place during specific periods of the year: basically, weekdays during the winter months. **While this period accounts for only 25% of the time of the year, 76% of the flexibilities activations would statistically take place during this period.**

However, as illustrated in Figure 6, it should be underlined that the likely periods of use may vary much from one climatic scenario to another.

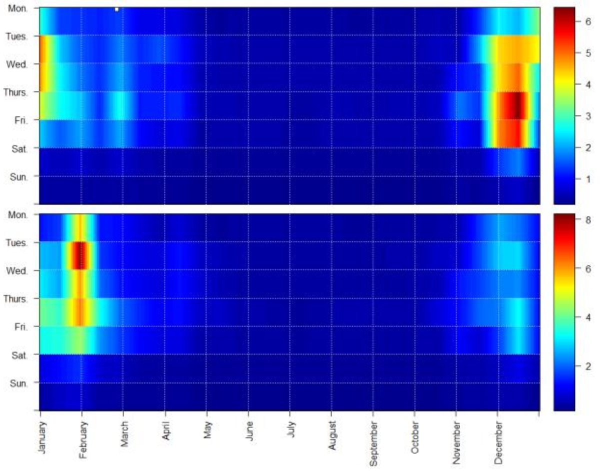

Figure 6: Statistical need for flexibilities over the year for two different climatic scenarios (mean=1)

Flexibility use case
Given that the investment is based in this case study on the EENS during incidents, the use cases of the flexibilities are necessarily related to the main types of incident that can occur in this primary substation.

Thus, one should keep in mind that the flexibility usage will not depend only on the consumption level but also on the incidents actually happening (which are unpredictable at the moment and do not happen on a regular basis). Consequently, in this case study, the flexibility activations would probably be rare.

CASE STUDY #2

Description of the case study

This second case study concerns a distribution grid which is fed by a single HV/MV 36 MVA transformer.

The addition of a second HV/MV 36 MVA transformer is under study as pre-studies show that if the existing HV/MV transformer fails, a large number of loads could no longer be supplied for a significant period of time. Therefore it would be more beneficial to invest in a second transformer rather than to risk these power outages.

The study being carrying out over a 30 year period, the investment is planned initially for the fourth year.

Characteristics of the required flexibilities

Minimum requirements for an investment deferral of one year
The results show that the minimum power capacity required to differ the investment reaches **1,100kW** for the maximum value scenario and **5,000kW** for the homogeneous distribution scenario [5].

Valuation of the flexibilities

Annual value

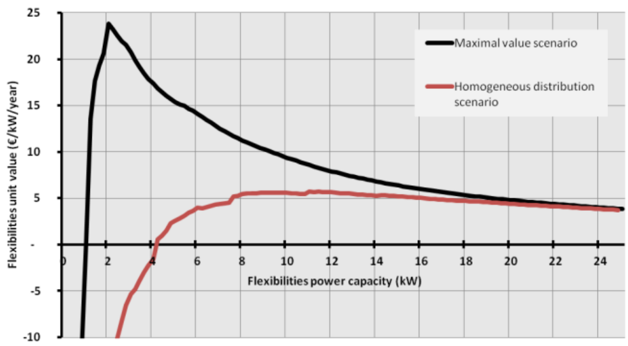

Figure 7: Flexibilities unit yearly value for an investment deferral of a year

Figure 7 shows that for this second case study, the maximum unit yearly value of the flexibilities reaches 5€/kW/year and 24€/kW/year for the two flexibility distribution scenarios: the valuation of the flexibilities depends greatly on how they are implemented.

Societal value and value structure
The results are rather similar to the first case study with one notable difference: **postponing the investment increases the benefits in terms of technical losses**. It is associated, in this case, with a €5k reduction of the technical losses costs.

5 These power capacities represent 3 and 13 percents of the maximal consumption of this primary substation.

Sensitivity to the activation delay

Sensitivity of the annual value to the activation delay

The results on this matter are similar to those described in Figure 3 except that in this case study, almost no value can be captured when the activation delay exceeds 18h.

Characteristics of the period of use

Sensitivity to the consumption scenarios

Contrary to the first case study, Figure 8 shows that for the second case study, a few climatic scenarios will statistically result in longer activations of the flexibilities: the use of flexibilities is to a larger extent dependent upon the climatic scenario in this case study.

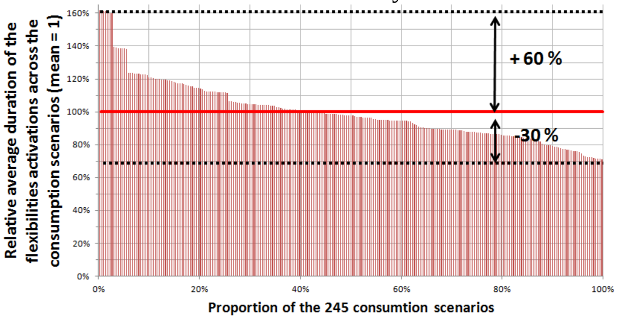

Figure 8: Description of the statistical duration of the flexibilities activations (mean=100%)

Periods of use

Figure 9 shows how the flexibilities activations would statistically be distributed over the year.

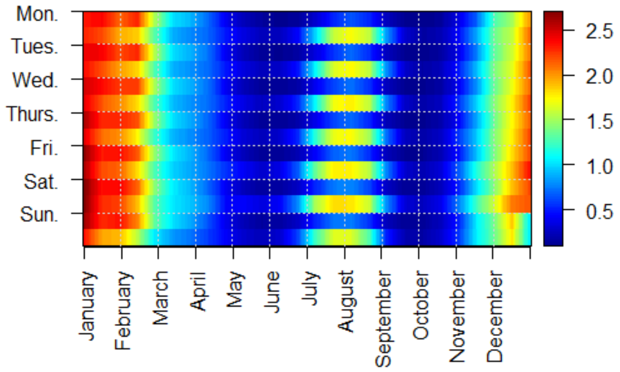

Figure 9: Statistical need for flexibilities over the year (average for 245 climatic scenarios / mean=1)

Unlike the first case study, it appears that the flexibilities activations are grouped within two main periods:
- December to February with almost no distinction between weekdays and weekends;
- Afternoons of July and August.

This unusual profile relates to the seaside tourism economy on which relies the area supplied by this substation.

Flexibility use case

Similarly to the first case study, the investment being based on the EENS during incidents, the use cases of the flexibilities are necessarily related to the main types of incident that can occur in this primary substation.

Thus, one should keep in mind that the flexibility usage will not depend only on the consumption level but also on the incidents actually happening (which are unpredictable at the moment and do not happen on a regular basis). Consequently, in this case study, the flexibility activation would probably be rare.

CONCLUSION

Conclusion of the case studies

The application of the methodology on the selected case studies has provided detailed information on the use of flexibilities in order to postpone an investment:
- the minimum requirements in terms of power capacity have been estimated ;
- the unit yearly value gave an insight on the maximum cost that the use of flexibility can reach while remaining economically beneficial ;
- the sensitivity of the value to the activation delay has emphasised the delays under which most of the value can be captured;
- the sensitivity of the statistical use of the flexibilities from one climatic scenario to another has been described;
- the periods of use during the year have been highlighted as well as the distribution over the days of the week.

The two case studies have confirmed that the **local consumption patterns as well as the local grid configurations** play a key role for understanding which types of flexibilities could be useful to the distribution grid.

Therefore, at the moment, it does not appear feasible to apply this methodology otherwise than one substation at a time using its specific characteristics.

Further work

The two different distribution scenarios have highlighted the significance of modelling how the flexibilities are distributed over the grid for estimating the unit value or the required power capacity of the flexibilities.

Although the two distribution scenarios described in this article provide a useful overview in terms of order of magnitude, they present an idealised representation of the flexibilities used. Further work could address the subject of flexibility format to obtain more realistic scenarios.

REFERENCES

[1] A. Bouorakima, J. Boubert, M.-A. Lafittau, “Valuation of consumption flexibilities in distribution system planning”, *Proc. CIRED WS 2016*, paper 0334.