Study on the value of flexibility in the management and design basis of distribution networks in France

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This document is a translation of E-CUBE Strategy Consultants' synthesis work, that has been conducted by the Commission de régulation de l'énergie *(National Regulatory Authority in France).*

CONTENTS

TABLE OF FIGURES

1 EXECUTIVE SUMMARY

The French electricity distribution networks (medium and low voltage) are subject to a range of changes, such as the increase of the connections of renewable energy sources (RES) and the natural growth of peak consumption, **which lead to constraints** (voltage and current) **on the infrastructure, and which require investment in reinforcements** in the various components of the network: HV/MV transformers[1], MV feeders[2]and MV/LV transformers[3].

At the same time, the development of decentralised sources of flexibility such as load curtailment (distributed or industrial), stimulated by national mechanisms, and the reduced cost of some technologies such as electricity storage **offer new solutions to Distribution System Operators (DSOs)** and may, in some cases, provide local alternatives to network reinforcement.

In this study, **flexibility** is defined as a temporary increase or decrease in the energy exchanged with the network, **managed in real time[4]** (manually or automatically)[5], based on the needs of the DSO and according to the local situation.

The study of flexibility in distribution networks is a new and complex exercise: the limited number of cases implemented internationally (apart from demonstrators) reflects this[6]. This complexity stems mainly from the diversity and number of situations encountered. Thus, in the French distribution network, there are approximately 2,200 primary substations (defined as substations at the interface between HV and MV networks), 20,000 MV feeders and 700,000 MV/LV substations[7].

The purpose of this work is to analyse **fifteen "case studies"[8],** in order to illustrate **the potential value of flexibility for distribution networks and the underlying economic rationale.** To do this, these studies are aimed initially at characterising the **potential income of flexibility** (i.e. the value of delaying investment in reinforcement that it allows), and subsequently, at estimating **the costs of flexibility** required to capture this income. The "net" value of flexibility is defined as the difference between income and costs. Only the direct economic value of flexibility is analysed in this report: the environmental impact and knock-on effect on employment are not taken into consideration. Furthermore, study of the *market design* of flexibility (contracting method, division of responsibilities, financial equalization, etc.) is not included in the scope of the study. At this stage, nine main conclusions may be drawn:

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[1] High (> 63 kV) to medium voltage (15/20 kV) transformer.

[2] Medium voltage current distribution lines (15/20 kV).

[3] Medium (> 15/20 kV) to low voltage (400 V) transformer. The scope of the study does not include "low voltage" feeders.

[4] Energy saving is therefore not considered as flexibility.

[5] Automatic management may be the activation of load curtailment linked to too low voltage measurement, whilst manual management would correspond to manual activation of load curtailment following a projected peak in consumption.

[6] We have conducted a benchmarking exercise covering a series of initiatives: in the United Kingdom (Electricity North West, Northern Powergrid and UK Powergrid), Australia (Ergon Energy) and Canada (BC Hydro).

[7] The primary substation includes the HV/MV transformers. The MV/LV substation includes the MV/LV transformers.

[8] Case studies are realistic examples of constraints in distribution networks, where flexibility (load curtailment, storage, peak shaving, etc.) may be an alternative to investment in reinforcement.

1. When a constraint appears, which is the case in **a limited part of the distribution networks each year**[9], **the potential income per kW of required flexibility can be established locally at an average level**[10] **of approximately €30 to €90/kW/year.** This income is derived, depending on the case, from delaying investment or the reduction of unserved energy[11]; the estimated values are comparable to, or even greater than the current value of flexibility at national level[12].

2. **Annual income varies considerably, however, depending on the case study,** from 0 to more than €200/kW/year, depending on the type of equipment reinforced (transformer or network) **and according to the time.** Income is therefore concentrated in the five years following the appearance of the constraint, i.e. when the depth of the constraint[13] is limited. **Income is, for the MV network, generally more significant in the rural case studies.**

3. **Extracting this income requires flexibility to be able to respond to the "constraint configuration".** This "constraint configuration" may be described using the same attributes as the national flexibility products[14]: maximum power, total call duration for the year, call frequency, maximum consecutive call duration. This configuration is considered to be "short" [15] (short call durations, be they consecutive or total for the year) for case studies related to HV/MV transformers, or constraints related to photovoltaic power genetation or residential consumption. Conversely, it is considered to be "long"[16] for cases related to wind turbine power generation or industrial consumption.

4. **Analysis shows that, in several case studies, the costs** of the various **flexibility** solutions capable of responding to these constraint configurations **are lower than the income generated** (ratio between Euros saved and Euros spent is greater than 1)**.**

5. **For constraints related to withdrawal** (consumption too high), **flexibility** from industrial load curtailment and back-up generators **have positive results** especially for short constraint configurations.

6. **For constraints related to injection** (production too high), **dynamic peak shaving of production has very positive results in all cases** (the ratio between Euros saved and Euros spent exceeds 10).

7. **Positive income/costs outcomes** for solutions such as **storage or distributed load curtailment** are restricted to more specific cases for **low-cost scenarios**[17].

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[9] The values presented in this study are valid only locally, within the scope of each case study and for the power ratings under constraint. These are not equalized values, which would correspond to average flexibility values at national level, and which should take into account all of the cases where there is no value for flexibility.

[10] The values presented are the average income over five years for all case studies.

[11] However, in the study, only the delayed investment is taken into account, because it is considered as an upper bound of the income generated by the reduction of unserved energy. It is therefore supposed that flexibility is only used when the cost of unserved energy reaches the cost of reinforcement.

[12] This income does not foresee the constraints configuration, which will have consequences for the cost of flexibility. These configurations vary considerably, depending on the case studies, and change over time (Figure 4).

[13] Depth corresponds to the surplus power (injection or withdrawal) creating the constraint.

[14] For example, the call for tender about load curtailment organised by the Transmission System Operator in France.

[15] "Short": total call duration lower than 50 hrs/year or consecutive call duration lower than 10 hrs.

[16] "Long": total call duration greater than 400 hrs/year or consecutive call duration greater than 20 hrs.

[17] Scenarios retaining the low range of costs observed in 2015 (€300/kWh and €900/kW).

8 **In addition to the theoretical analysis of flexibility, the study of the practical conditions involved in implementing flexibility shows that the methods and tools used by DSOs for network planning and flexibility implementation can drive up and down the value of flexibility**.

9 In conclusion, this study shows that flexibility is of value for electricity distribution networks, at least from a theoretical point of view in some of the “case studies”, and in all likelihood also in practice, in certain situations**.** However, **this study does not provide any results on the overall potential of the value of flexibility at national level.** Several other studies must be undertaken to determine this potential, **as well as to define the regulatory framework and the market design that would promote its use for the national community.** Incorporating failure of the flexibility in terms of its design basis[18], the sharing of responsibility and penalties resulting from failure will be some of the decisive factors in successfully using the flexibility.

2 REVIEW OF THE CONCLUSIONS

2.1 When a constraint appears, which is a case in a limited part of the distribution networks each year, the potential income per kW of required flexibility can be established locally at an average level of approximately €30 to €90/kW/year. This income is derived, depending on the case, from delaying investment or the reduction of unserved energy; the estimated values are comparable to, or even greater than the current value of flexibility at national level.

In their reference state, the components of the distribution networks are suited to current needs and are therefore not under constraint. In this case, there is no first order flexibility value[19]. The constraints appear with changes in energy consumption and generation on the networks. Each year, a limited number of distribution network components are subject to new constraints.

In these constraint situations, the potential income of flexibility per kW for each network equipment type (HV/MV transformers, MV feeders and MV/LV transformers) is established locally at an average level between €30 and €90/kW/year (Figure 1): the average income of each equipment type is calculated as the average, for the case studies[20] and over five years, of the annual income. This income is expressed in €/kW/year, which means it can be compared with flexibility values at national level. We can therefore note that the order of magnitude of the flexibility income in the distribution networks is at a similar level or even greater than the income observed for flexibility at national level[21]. This income does not foresee the configuration of the constraints, which will have consequences for the cost of flexibility. These forms vary considerably, depending on the case studies, and change over time (Figure 4).

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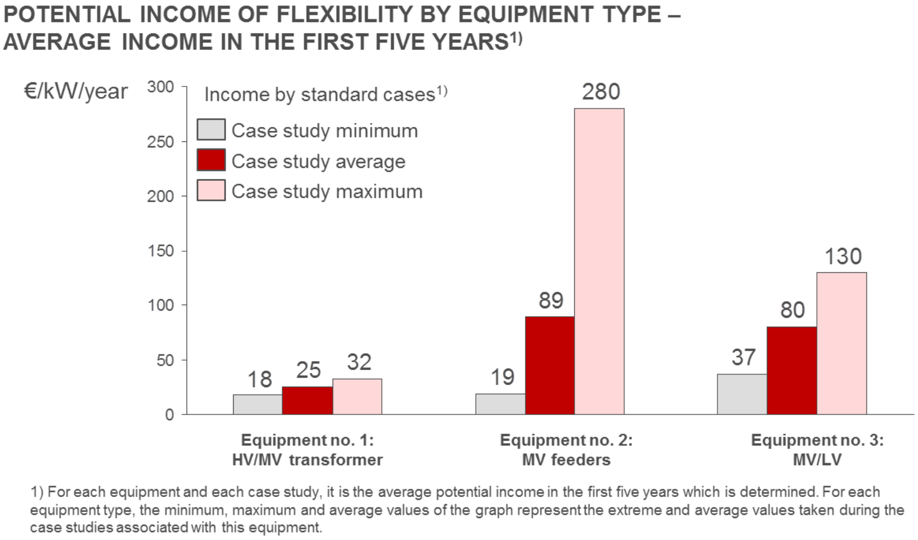
[18] Failure of the flexibility may be incorporated differently depending on the “N” or “N-1” situation of the relevant constraint.

[19] Second order flexibility may be valued as an improvement in quality, especially by reducing Non-Distributed Energy

[20] 2 to 9 case studies per equipment type. 14 case studies in total.

[21] Approximately €3/kW/year for the load curtailment invitation for tenders (in 2015) (20 annual activations, for a maximum consecutive call duration of 1 to 4 hours) to approximately €36/kW/year for the service sector reserves invitations for tenders (capacities must be available every day with two activations per day, over a consecutive call duration of at least 30 mins and up to one hour) organised by the transmission grid manager.


POTENTIAL INCOME OF FLEXIBILITY BY EQUIPMENT TYPE – AVERAGE INCOME IN THE FIRST FIVE YEARS1)

1) For each equipment and each case study, it is the average potential income in the first five years which is determined. For each equipment type, the minimum, maximum and average values of the graph represent the extreme and average values taken during the case studies associated with this equipment.

Figure 1: Potential income of flexibility by equipment type – average income in the first five years

Methodology elements

The study considers fifteen case studies. Case studies are realistic examples of constraints in distribution networks, where flexibility (load curtailment, storage, production peak shaving, etc.) may be an alternative to investment in reinforcement.

Each case study is subject to changes in energy generation and consumption over a 15-year period. A technical and economic model based on electro-technical principles analyses the response of the network to these changes: for each case, the model first of all assesses the potential income, then the configuration of the constraint and finally the cost of each flexibility form in response to the constraint, in order to determine the net flexibility value.

1. Potential income represents the costs avoided in the grid thanks to flexibility. These avoided costs come from delayed investment or a reduction in unserved energy[22].
2. The constraint configuration is determined by the exceedance of some technical thresholds (power, current or voltage), which are defined by the current regulatory criteria[23] for the design basis of distribution networks. According to the case study, these are the (i) current (MV/LV transformers, MV network) and (ii) voltage (MV network) thresholds or when the cost of unserved energy exceeds the cost of network reinforcement (iii). This analysis has been conducted on load curves at hourly intervals (8,760 points) over the 15 years of the study. For the MV network case study, the calculations are discretised throughout the network, with 10 calculation points for each MV feeder.
3. Each flexibility is designed to respond to the "configuration" of the constraints, which enables a suitable cost to be evaluated for each case study and each flexibility technology, and therefore the net value generated by each flexibility.

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[22] However, in the study, only the delayed investment is taken into account, because it is considered as an upper bound of the income generated by the reduction of non-distributed energy. It is therefore supposed that flexibility is only used when the cost of non-distributed energy reaches the cost of reinforcement.

[23] These rules are described in the technical reference documentation managed by the CRE.

This value is an overall estimate for the community. It cannot be equated with the explicit remuneration of the flexibility, since it does not take into account certain external factors (such as transmission grid pricing or the other flexibility values), and moreover that flexibility is also implicitly remunerated by the cost savings in the use of public electricity networks charges, resulting from lower levels of consumption (for downward flexibility).

2.2 Annual income varies considerably, however, depending on the case study, from 0 to over €200/kW/year, depending on the equipment type reinforced (transformer or network) and according to the time. Income is therefore concentrated in the five years following the appearance of the constraint, i.e. when the depth of the constraint[24] is limited. Income is, for the MV network, generally more significant in the rural case studies.

We have already highlighted the fact that the distribution network has multiple and varied situations. We note that this diversity is reflected in the substantial variations in income noted between the case studies for a given equipment type (illustrated by the minimum and maximum values observed in the case studies in Figure 1). One of the key variables of this sensitivity is the importance of topology (length of network, urban, semi-urban or rural network).

The potential income of flexibility appears higher for the MV network. This is particularly true for case studies in rural areas, and this can be explained by the network being longer on average than in urban areas. Length combines two factors that favour flexibility: the total cost of reinforcement is proportionate to the length of the network to be reinforced, meaning that costs are high for long networks and so therefore is income[25]; voltage constraints are more marked, with the same power, for a long network.

Furthermore, for the same case study, flexibility incomes will vary considerably over time. This variation depends on the pace at which the constraint grows (e.g., growth of photovoltaic power generation at a feeder). The quicker it is, the more the depth of the constraint (kW) will quickly increase, thus reducing income in €/kW/year by as much.

Income fluctuates between 0 and over €200/kW/year, depending on the reinforced equipment type[26].

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[24] Depth corresponds to the surplus power (injection or withdrawal) creating the constraint.

[25] The study does not take into account the external factors involved in reinforcement, such as the improved quality obtained through burying power cables by reducing the expected cut-off times of customers.

[26] However, the absolute value of the available potential income of flexibility (k€) is significantly higher for the case study concerning the HV/MV transformer, because this type of equipment is significantly bigger than the others.

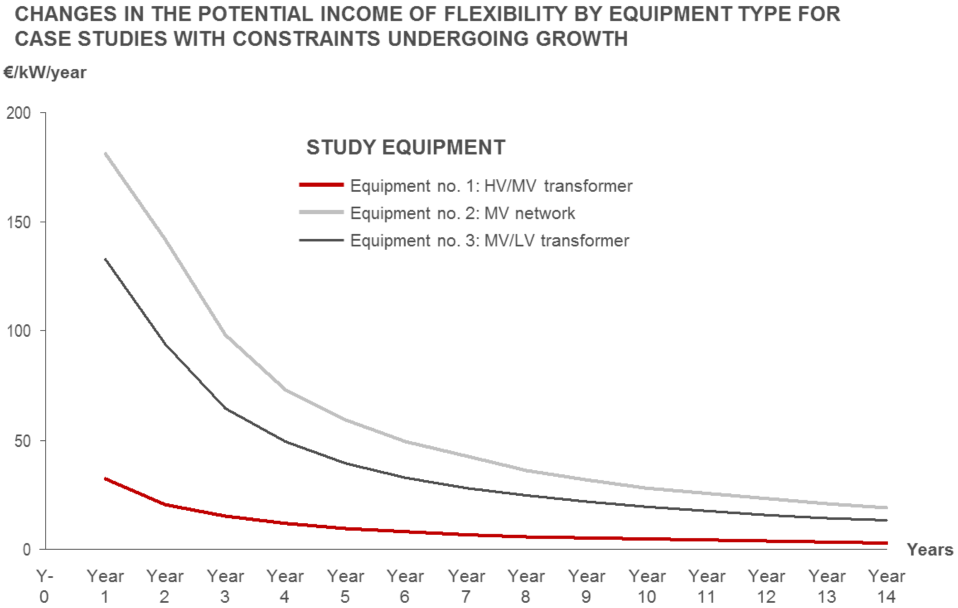

Figure 2: Changes in the potential income of flexibility by equipment type for case studies with constraints on growth

As illustrated in Figure 2, income is therefore concentrated in the five years following the appearance of the constraint, i.e. when the depth of the constraint is limited.

2.3 Extracting this income requires flexibility to be able to respond to the "constraint configuration". This "constraint configuration" may be described using the same attributes as the national flexibility products[27]: maximum power, total call duration for the year, call frequency, maximum consecutive call duration. This configuration is considered to be "short" (short call durations, be they consecutive or total) for case studies related to HV/MV transformers, or constraints related to photovoltaic power generation or residential consumption. Conversely, it is considered to be long for cases related to wind turbine power generation or industrial consumption.

Regulatory criteria determine the maximum acceptable power for the various equipment types[28]: a tolerated margin (110% of nominal power) for HV/MV transformers in "*N*-1" situations (i.e. with a network failure); a maximum current in "*N*-1" situations in MV networks; voltage thresholds that must not be exceeded in "*N*" situations (without network failure) for MV networks; a tolerated margin (110% of nominal power) for MV/LV transformers in "*N*" situations.

For all cases in "*N*-1" situations, failure to observe the regulatory criteria does not necessarily mean reinforcement investment: a cost analysis of the unserved energy is conducted.

This maximum acceptable power is compared with the load curve to which the equipment installation is expected to respond. The load curve is considered as being an average load curve in terms of climate variation[29]. Any point exceeding the maximum acceptable power[30], in injection or withdrawal, is

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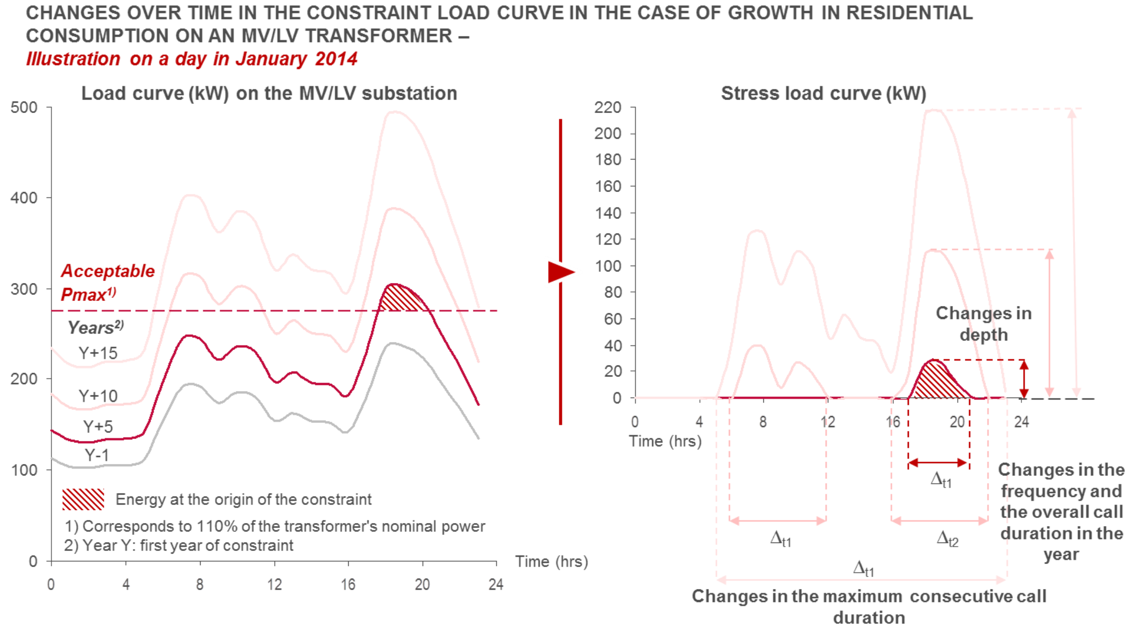
[27] For example, the call for tender about load curtailment organised by the Transmission System Operator in France.

[28] For networks with constraints in *N* situations, acceptable power is spatial, i.e. it varies according to the network point in question.

[29] Current regulatory criteria involve reasoning using average constraint load curves in terms of climate variation. Other criteria, such as those used by the transmission grid (3 hrs per year), could lead to more complex analyses of random events and risks, particularly climate-related, involving probabilistic approaches such as the Monte-Carlo method.

a constraint. All of these points define a “constraint load curve”. As shown in Figure 3, the constraint load curve changes over time as energy consumption or generation grows.



CHANGES OVER TIME IN THE CONSTRAINT LOAD CURVE IN THE CASE OF GROWTH IN RESIDENTIAL CONSUMPTION ON AN MV/LV TRANSFORMER –
Illustration on a day in January 2014

Figure 3: Changes over time in the constraint load curve

The “constraint configuration” is a conventional representation of the constraint load curve. It is defined in a similar way to the products of national flexibility[31]: maximum power (mirroring the maximum depth of the constraint), total call duration for the year, call frequency, maximum consecutive call duration.

This configuration is “short” (total call duration lower than 50 hrs/year or consecutive call duration lower than 10 hrs) for case studies involving HV/MV transformers or constraints related to photovoltaic power generation or residential consumption. It is “long” (total call duration greater than 400 hrs/year or consecutive call duration greater than 20 hrs) for case studies involving constraints related to wind turbine power generation, combined heat and power generation or “flat” industrial consumption. One international benchmarking exercise confirms that distributors are purchasing short products similar to those determined by the analyses[32].

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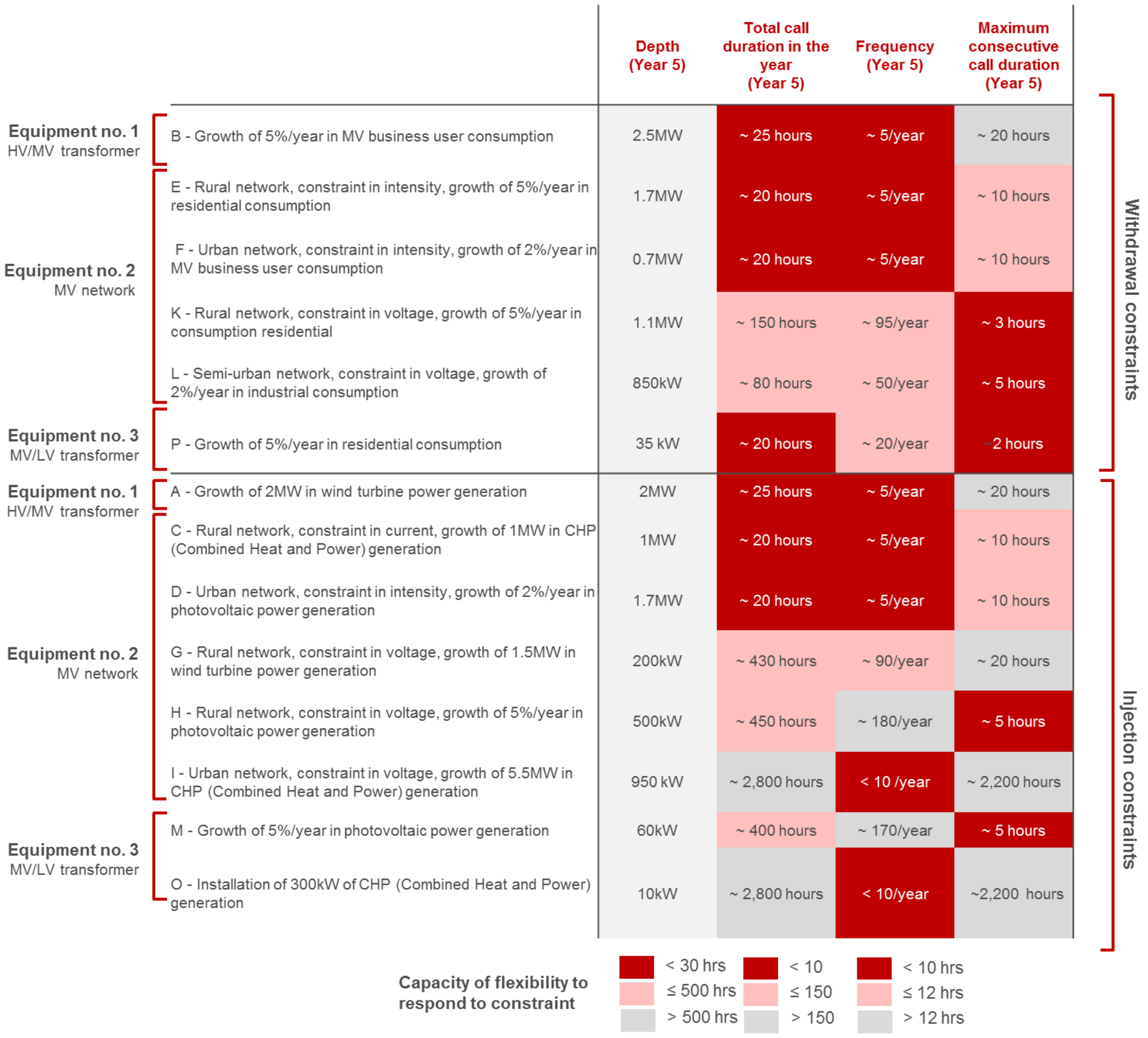
[30] For cases covered by “*N*-1” situations, the characteristics of the duration and frequency of network failures are the factors that determine first and foremost the constraint load curve.

[31] For example, the distributed load curtailment invitation to tender organised by the transmission grid manager.

[32] For the distributor ENWL, load curtailment capacities were purchased for activation ten times per year between October 1st and March 31st, each activation lasting three hours.



			Depth (Year 5)	Total call duration in the year (Year 5)	Frequency (Year 5)	Maximum consecutive call duration (Year 5)
Withdrawal constraints	**Equipment no. 1** HV/MV transformer	B - Growth of 5%/year in MV business user consumption	2.5MW	~ 25 hours	~ 5/year	~ 20 hours
	Equipment no. 2 MV network	E - Rural network, constraint in intensity, growth of 5%/year in residential consumption	1.7MW	~ 20 hours	~ 5/year	~ 10 hours
		F - Urban network, constraint in intensity, growth of 2%/year in MV business user consumption	0.7MW	~ 20 hours	~ 5/year	~ 10 hours
		K - Rural network, constraint in voltage, growth of 5%/year in consumption residential	1.1MW	~ 150 hours	~ 95/year	~ 3 hours
		L - Semi-urban network, constraint in voltage, growth of 2%/year in industrial consumption	850kW	~ 80 hours	~ 50/year	~ 5 hours
	Equipment no. 3 MV/LV transformer	P - Growth of 5%/year in residential consumption	35 kW	~ 20 hours	~ 20/year	~2 hours
Injection constraints	**Equipment no. 1** HV/MV transformer	A - Growth of 2MW in wind turbine power generation	2MW	~ 25 hours	~ 5/year	~ 20 hours
	Equipment no. 2 MV network	C - Rural network, constraint in current, growth of 1MW in CHP (Combined Heat and Power) generation	1MW	~ 20 hours	~ 5/year	~ 10 hours
		D - Urban network, constraint in intensity, growth of 2%/year in photovoltaic power generation	1.7MW	~ 20 hours	~ 5/year	~ 10 hours
		G - Rural network, constraint in voltage, growth of 1.5MW in wind turbine power generation	200kW	~ 430 hours	~ 90/year	~ 20 hours
		H - Rural network, constraint in voltage, growth of 5%/year in photovoltaic power generation	500kW	~ 450 hours	~ 180/year	~ 5 hours
		I - Urban network, constraint in voltage, growth of 5.5MW in CHP (Combined Heat and Power) generation	950 kW	~ 2,800 hours	< 10 /year	~ 2,200 hours
	Equipment no. 3 MV/LV transformer	M - Growth of 5%/year in photovoltaic power generation	60kW	~ 400 hours	~ 170/year	~ 5 hours
		O - Installation of 300kW of CHP (Combined Heat and Power) generation	10kW	~ 2,800 hours	< 10/year	~2,200 hours

Capacity of flexibility to respond to constraint

🟥	< 30 hrs	< 10	< 10 hrs
▨	≤ 500 hrs	≤ 150	≤ 12 hrs
⬜	> 500 hrs	> 150	> 12 hrs

Figure 4: Constraint configuration five years after start of constraint, according to case study

2.4 Analysis shows that, in several case studies, the costs of the various flexibility solutions capable of responding to these constraint configurations are lower than the income generated (ratio between Euros saved and Euros spent is greater than 1).

We study the performance of five flexibility solutions in their response to the “constraint configurations” defined above: industrial load curtailment; distributed load curtailment; back-up generators (excluding the value of external environmental factors); storage; peak shaving of renewable energy sources. For each flexibility solution, we define a low-cost scenario and a high-cost scenario, based on reference studies. All of these flexibility solutions appear in the benchmarking exercises conducted.

In order to compare results across the various equipment types, and even though potential income amounts are not of the same order of magnitude, the chosen metric is the Euros saved on delayed investment for Euros spent on flexibility ratio. A ratio of more than one indicates that the net flexibility value is positive, whereas a ratio of less than one shows that the flexibility has a negative net value.

Net flexibility value in the distribution networks appears positive for each equipment type, at least as regards the use of certain flexibility solutions (Figure 5). The results vary, however, according to the assumptions made, especially as regards the cost scenarios.

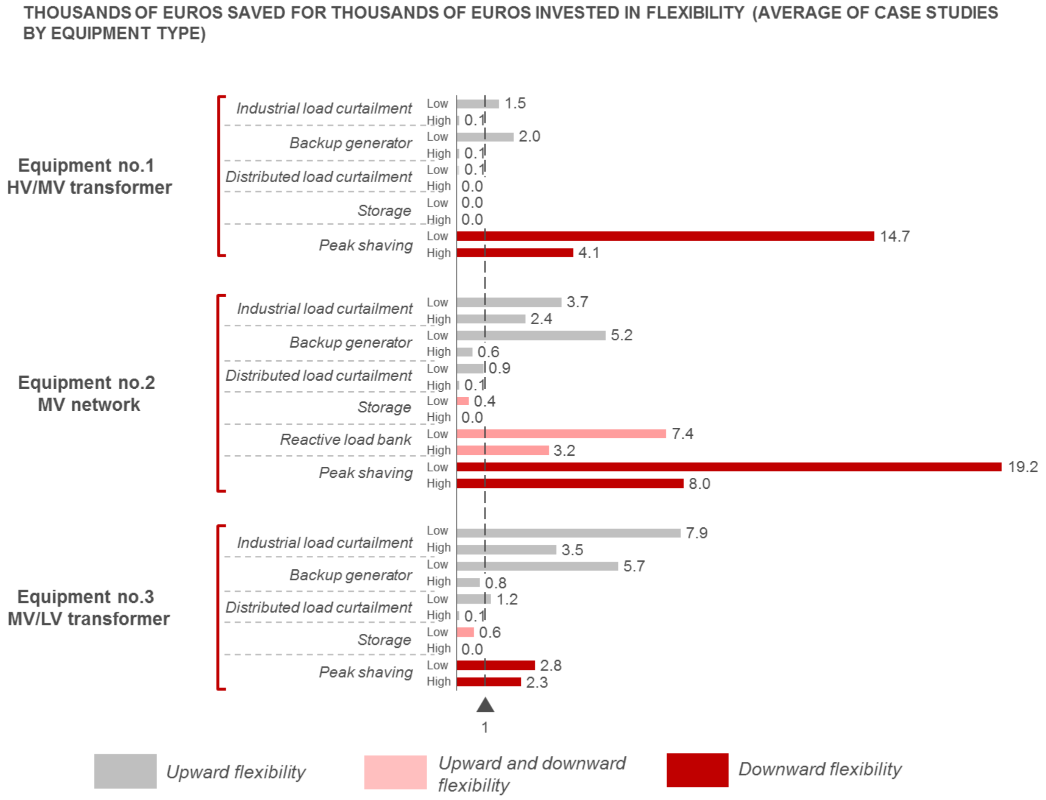
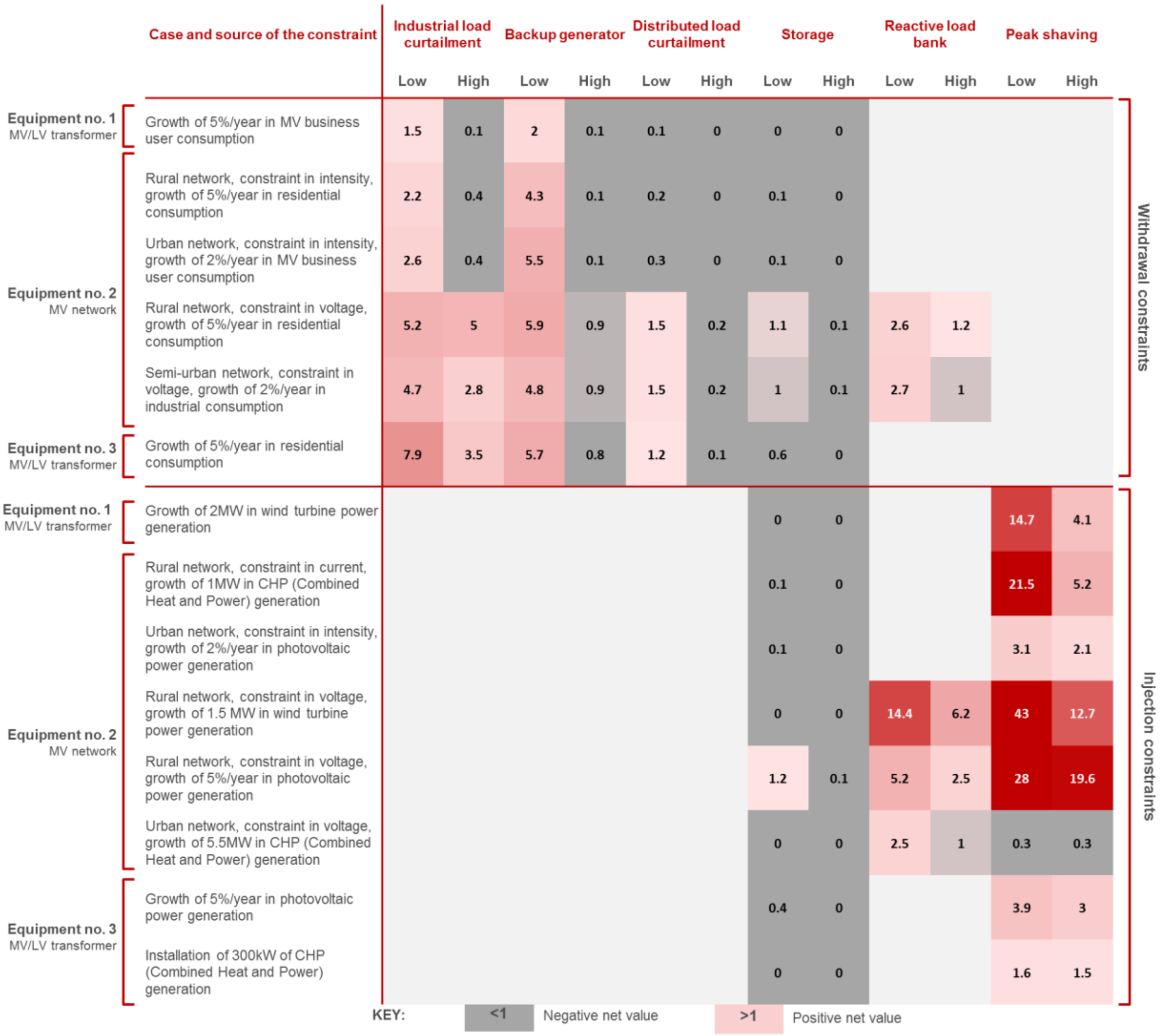


Figure 5: Euros saved for Euros invested in flexibility by case study (average of case studies by equipment type)

The result of the analysis on each individual case study, in Figure 6, confirms this observation. However, the detail of the case studies also highlights the variations in net values depending on the specific conditions of each case. Net value is the direct result of discrepancies noted between potential income and the constraint configuration, and these two elements have both proven to be highly variable in the case studies. Lastly, the case study figures provide evidence that net value levels are generally higher in MV networks than on other equipment types.

The ratios below one show that income in the distribution networks is insufficient to offset the costs, but they do not necessarily mean that the flexibility resources will not be used, insofar as other income may be valued through other processes, such as the adjustment mechanism market and the capacity market.

EUROS SAVED FOR EUROS INVESTED IN FLEXIBILITY BY CASE STUDY



		Case and source of the constraint	Industrial load curtailment		Backup generator		Distributed load curtailment		Storage		Reactive load bank		Peak shaving	
			Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Withdrawal constraints	**Equipment no. 1** MV/LV transformer	Growth of 5%/year in MV business user consumption	1.5	0.1	2	0.1	0.1	0	0	0				
	Equipment no. 2 MV network	Rural network, constraint in intensity, growth of 5%/year in residential consumption	2.2	0.4	4.3	0.1	0.2	0	0.1	0				
		Urban network, constraint in intensity, growth of 2%/year in MV business user consumption	2.6	0.4	5.5	0.1	0.3	0	0.1	0				
		Rural network, constraint in voltage, growth of 5%/year in residential consumption	5.2	5	5.9	0.9	1.5	0.2	1.1	0.1	2.6	1.2		
		Semi-urban network, constraint in voltage, growth of 2%/year in industrial consumption	4.7	2.8	4.8	0.9	1.5	0.2	1	0.1	2.7	1		
	Equipment no. 3 MV/LV transformer	Growth of 5%/year in residential consumption	7.9	3.5	5.7	0.8	1.2	0.1	0.6	0				
Injection constraints	**Equipment no. 1** MV/LV transformer	Growth of 2MW in wind turbine power generation							0	0			14.7	4.1
	Equipment no. 2 MV network	Rural network, constraint in current, growth of 1MW in CHP (Combined Heat and Power) generation							0.1	0			21.5	5.2
		Urban network, constraint in intensity, growth of 2%/year in photovoltaic power generation							0.1	0			3.1	2.1
		Rural network, constraint in voltage, growth of 1.5 MW in wind turbine power generation							0	0	14.4	6.2	43	12.7
		Rural network, constraint in voltage, growth of 5%/year in photovoltaic power generation							1.2	0.1	5.2	2.5	28	19.6
		Urban network, constraint in voltage, growth of 5.5MW in CHP (Combined Heat and Power) generation							0	0	2.5	1	0.3	0.3
	Equipment no. 3 MV/LV transformer	Growth of 5%/year in photovoltaic power generation							0.4	0			3.9	3
		Installation of 300kW of CHP (Combined Heat and Power) generation							0	0			1.6	1.5

KEY: <1 Negative net value >1 Positive net value

Figure 6: Euros saved for Euros invested in flexibility by case study

2.5 For constraints related to extraction (consumption too high), flexibility from industrial load curtailment and generators have positive results especially for short constraint configurations.

Industrial load curtailment and back-up generators (not taking into account external environmental factors) have positive results in a certain number of case studies, especially in favourable cost scenarios. These two assets are favoured due to their relatively low fixed costs. For industrial load curtailment, this is particularly true for short constraint configurations, because this asset responds more easily to constraints than a long-lasting activation.

There are however significant uncertainty surrounding the matching of the flexibility source capabilities and local flexibility requirements, in terms of volume and cost. The benchmarking exercises, excluding demonstrators[33], show the complexity involved in mobilising a load curtailment source at the scale of a distribution network.

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[33] Case of ENWL in the United Kingdom: the use of load curtailment was interrupted due to a lack of local industrial load curtailment source, at the primary substation under constraint.

2.6 For constraints related to injection (production too high), dynamic peak shaving of production has very positive results in all cases (the ratio between Euros saved and Euros spent exceeds 10).

Dynamic peak shaving involves reducing local electricity generation temporarily to avoid generating too much power for the network[34]. With ratio between Euros saved and Euros spent exceeding 10, dynamic peak shaving has very positive results in all cases. These significant ratios can be explained by the limited cost of flexibility: low energy volumes and low energy value assumptions.

Given these values, some renewable energy project initiators have already reduced the size of their facilities, in order to reduce or avoid connection or reinforcement costs altogether. Aside from experimentation[35], however, there is currently no evidence of “dynamic” management of the peak shaving.

To a lesser extent, reactive load banks seem to provide a relevant solution for injecting reactive power when faced with voltage issues.

2.7 Positive income/costs outcomes for solutions such as storage or distributed load curtailment are restricted to more specific cases for low-cost scenarios.

Storage and load curtailment technologies are hampered by the high investment costs involved, which are not absorbed over the five-year period during which the deferral value is concentrated. The low-cost scenario, which assumes that stranded costs can be covered by other uses (for example, repositioning a container of batteries in another constraint area), has positive results in several case studies (rural and semi-urban networks with short format constraints).

A scenario where values are pooled by the distribution networks and the national electricity system (energy trade-off, capacity market, and ancillary services) could improve the profitability of such solutions.

2.8 In addition to the theoretical analysis of flexibility, the study of the practical conditions involved in implementing flexibility shows that the methods and tools used by DSOs for network planning and flexibility implementation can drive up and down the value of flexibility.

The factors limiting the flexibility value concern, on the one hand, network planning, i.e. the capacity to anticipate flexibility requirements, in terms of format and quantity, and therefore predict its value; and on the other hand, network operations, i.e. the capacity to use flexibility with the correct design basis, in real time, according to the appearance of constraints.

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[34] In this study, only dynamic peak shaving is retained, because it is the technology that meets the definition of flexibility in the study. Given this, connecting an electricity producer with an injection power limit, which may also allow investment to be delayed, is not considered. If these methods were in place, the dynamic peak shaving value would be limited to optimising capped energy costs.

[35] Especially as regards the use of the “DEIE” (operating information sharing system), which enables the DSO’s agents to operate generation facilities remotely.

	Favourable for flexibility	**Unfavourable for flexibility**
Factors related to planning	• Development of new constraint resolution options for planning	• Lack of local data (local load curves, spatialisation of data, etc.) • Uncertainty as regards measurements • Difficulty in separating reinforcements due to other reasons for investment (burying of power lines, improvements, etc.)
Factors related to operations	• Changes in DSO professions	• Real-time management of flexibility (notice of activation, activation, follow-up, etc.) • Operational requirements (resources, skills, IS) in order to implement flexibility
Factors related to energy transition	• Development of sources of flexibility • Development of constraints related to distributed power generation • Increase in energy efficiency and therefore rapid changes in use of the network	

Figure 7: Descriptions of factors that are favourable or unfavourable for flexibility value

The **analyses conducted as part of the study show that net flexibility value is very strongly influenced by these factors, as far as making it zero or negative in some cases** (such as that of the MV/LV transformer, where local data is currently lacking).

Furthermore, energy transition may be the cause of changes in electricity uses that will help flexibility, by altering network usage more quickly: a constraint may appear with the connection of new consumers, and then disappear a few years later with the development of electrical efficiency. In such a case, reinforcement would only be useful for a limited period of time.

2.9 In conclusion, this study shows that flexibility is of value for electricity distribution networks, at least from a theoretical point of view in some of the “case studies”, and in all likelihood also in practice, in certain situations. However, this study does not provide any results on the overall potential of the value of flexibility at national level. Several other studies must be undertaken to determine this potential, as well as to define the regulatory framework and the market design that would promote its use for the national community. Incorporating failure of the flexibility in terms of its design basis[36], the sharing of responsibility and penalties resulting from failure will be some of the decisive factors in successfully using the flexibility.

Additional required works particularly include the following:

- **The impact of the value synergies and/or constraints compared with national mechanisms**. This may prove decisive for certain solutions such as storage.
- **The source[37] of flexibility and how suited it is to local requirements**. International benchmarking exercises show that local sources of flexibility may be too limited to be able to resolve the constraints and delay investment. This may particularly be explained by a lack of consumption consolidation at local level or a lack of industrial customers capable of curtailment.
- **Estimating a flexibility value for the distribution networks at national level**. Extrapolating these “laboratory” results to the entire distribution network will require substantial modelling work to estimate an overall flexibility value.
- **The conception of an efficient market design for mobilising flexibility resources in various situations but with a low unit value** (from €20k to €500k of cumulated value per case). This shall take into account the challenges involved in integrating flexibility in the

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[36] Failure of the flexibility may be incorporated differently depending on the “*N*” or “*N*-1” situation of the relevant constraint.

[37] The source of flexibility is considered to be some locally available capacity that can supply flexibility to the distribution network. Sources are production, consumption, storage facilities and other electrical equipment installations connected to the network. The more restricted the scope of the case study or the lower the number of users involved, the more limited the source will be.

current tariff framework. By way of illustration, this integration should limit the possibility of using windfall effects that may result from variance between the potentially high local value, based on which the flexibility provided by a network user may be remunerated, and the rate paid by users for the constraints it creates itself, based on a standard and equalized tariff. The market design shall define, in particular, the conditions that must be met for the operating expenses (OPEX) incurred in implementing flexibility to be recognised and compensated by the public electricity network tariffs. They may also define the conditions in which flexibility may be subscribed (invitation for tender) or activated (especially in looking for optimisation compared with its possible concurrent use for supply-demand balance).

- It will also be necessary to **anticipate the risk of possible discrepancies between the real reliability of flexibility, observed in practice, and its theoretical reliability, initially stipulated in the contract**. Reliability requirements[38] will be a key point because the cost of unserved energy is very high and there will be no alternative solutions at local level in the event of failure for a constraint in a nominal situation (*N*[39]). DSOs may fear being made ultimately liable in case of flexibility supplier failure: the capacity of the operator to pay penalties is uncertain, as is the outcome of any legal claim; guarantees must be obtained in all cases.

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[38] When modelling, the reliability requirements are integrated as a flexibility requirement oversizing factor.

[39] Conversely, in *N*-1 situation, the short format constraint limits the economic impact of flexibility failure, because it is already the backup solution for a network failure.