ENEDIS
L'ELECTRICITE EN RESEAU

ADEeF
Association des Distributeurs d'Electricité en France

Economic assessment of smart grids solutions

Analysis carried out by the distribution network operators

Executive Summary 2017

The new paths of electricity

Economic assessment of smart grids solutions

Analysis carried out by the distribution network operators

Public distribution networks are supporting the energy transition by developing smart grids and study their economic viability.

The publication on 18 August 2015 of the Law regarding the Energy Transition for Green Growth[1] is a major development for electricity networks. This law sets some ambitious objectives regarding the production and use of decarbonised electricity, more specifically renewable production and electric mobility. These two uses, which primarily concern public distribution networks, call for innovative solutions and more adaptive networks. In this regard, the law also provides for a certain number of provisions regarding flexibility and self-consumption that supplement the deployment of new equipment and systems for the operation of distribution networks.

Public distribution networks play a key role in the territorial dynamic that is the energy transition. For several years, the distribution network operators have been supporting and facilitating the energy transition, particularly through a strong and multi-faceted innovation policy. They are highly committed to achieving their objectives in an increasingly effective way and are inventing the network of the future, which will be "smarter", more digital and more interactive for the benefit of customers, electricity market players and state authorities. To this end, the distribution network operators will, for example, make the most of the new services offered by the electric system participants.

This activity in the smart grid sector is growing internationally and has been consolidated in France with the creation in April 2015 of the association Think Smart Grids. Its main missions are to develop the smart grid sector in France and to promote French solutions in Europe and around the world.

In this context of transition, combined with ambitious objectives, a key concern is the question of the economic viability of these solutions. This was highlighted in a letter from the ministries for the Environment, Sustainable Development and Energy and for the Economy, Industry and Digital Technology, which requested additional information regarding this question with regard to the distribution and transmission networks. **This study is the contribution of the distribution network operators to this analysis. It forms part of the overall answer that ADEeF, ADEME, Enedis and RTE have been preparing for the ministries.**

This study aims to analyse the costs and benefits over the whole value chain of the selected functions between now and 2030 in the context of New Mix 2030, an electricity mix scenario which is described in RTE 2014's provisional report[2].

Thus, the study's objectives were to inform the public authorities and the smart grid sector about the economic value of smart grids for public distribution networks.

Smart grids in public distribution networks: an essential set of solutions for the success of the energy transition.

Smart grid solutions modernise the operation of networks. In particular, they aim to maintain the quality and continuity of supply at an optimal cost for the entire grid, to improve the performance of operations and the maintenance of networks, and to support the energy transition of local regions.

The analysis of the solutions contained in this study **informs stakeholders of the sector and state authorities about the functions that have now reached an advanced stage of maturity, their possible economic value, their role in the energy transition, and the deployment plans associated with them.**

The functions that were selected are as follows: extension of self-healing capabilities of the network, operational planning systems, centralised voltage control, self-adaptive reactive power control of distributed generation, active power curtailment of distributed generation and the use of flexibility to alleviate demand constraints.

Meaningful economic results based on the tools and methods of distribution network operators and coherent with the deployment plans, either at a national scale or to meet local needs.

The economic assessment of these advanced functions has led to the identification of different types of gains: reduction in energy not supplied, reduction in curtailed energy, reduction in losses in the networks, postponed or avoided investments, etc. **They provide an initial overview of the possible benefits of smart grid solutions for public distribution networks.**

The analyses make particular use of the tool used by Enedis in its operations to make investment decisions. This tool includes the modelling of physical networks and can be used to conduct real-life studies. **The results presented in this study are therefore coherent with actual investment decisions and foreshadow future action plans.**

This approach leads to different deployment scenarios depending on the solutions: some levers are deployed nationwide while others are targeted at situations with specific local characteristics.

1 - Law no. 2015-992 of 17 August 2015 regarding the energy transition for green growth.
2 - RTE, 'Provisional report on the balance of supply and demand for electricity in France', 2014.

The viability assessments were used to define the deployment criteria, particularly local characteristics, and for certain functions, to estimate the deployment volume for the French grid in 2030. For local issues, studies are to be conducted on a case by case basis to identify the best solution. This local component is fully integrated in the deployment process of smart grid solutions for public distribution networks.

Promising advanced functions in the context of the energy transition that provide added value for society.

The studied advanced functions all enable positive surpluses for society without making pre-assumptions regarding the distribution of these surpluses between the different stakeholders of the electricity system.

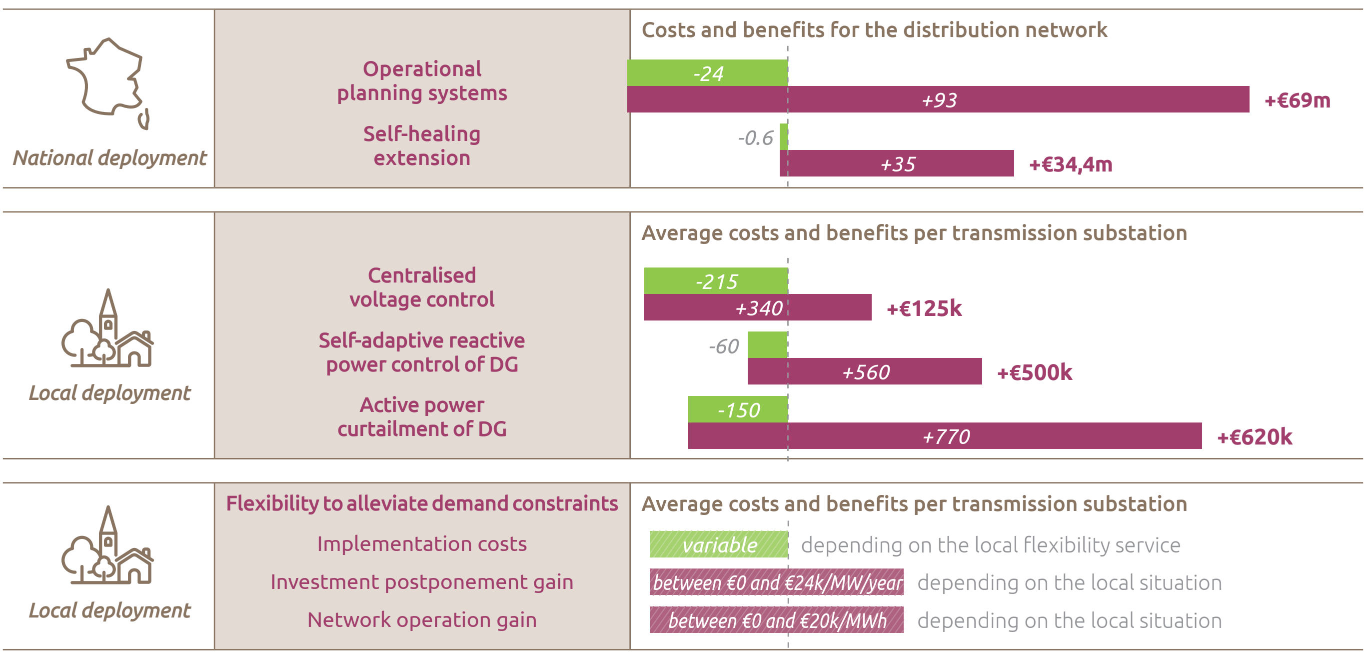
They contribute to the success of the energy transition through the:

- **Improvement in the quality of supply:** the extension of the self-healing capabilities of the network improves the resilience of the grid to outages, allowing customers to resume normal function faster following an incident. This constitutes a benefit for society of approximately €35m by 2030. The use of flexibility also contributes to improving the quality of supply by providing additional levers to enable the reconnection of customers.
- **Increased insertion of production:**
  - Operational planning systems will **improve the planning of maintenance works** for the networks. Considering the integration of significant MV production by 2030, these systems will reduce curtailed energy by 10% with no effect on the duration of the works or on the quality of the maintenance. Annual savings for society at large will be between €3m and €19m per year until 2030 as a result of the growth in renewable energy. The cumulated net gain (savings minus costs) for the entire grid by 2030 is estimated to be between €62m and €70m. This function is also an essential prerequisite for the implementation of other advanced functions (particularly centralised voltage regulation and the use of flexibility).
  - The self-adaptive reactive power control and active power curtailment of distributed generation can **improve the insertion of MV production by controlling their effects on the network:** the average net benefits are respectively €100k and €90k/MW for the MV installations concerned.
- **Improved adaptation to the local characteristics of the network in order to support the energy transition optimally:**
  - The levers related to voltage regulation and flexibility make it possible to manage situations with specific local constraints: their deployment will therefore be targeted in accordance with these specific situations.
  - The analysis at a nationwide level foresee the integration of around 220 MW of MV production thanks to self-adaptive reactive power control, and of around 720 MW thanks to active power curtailment, which corresponds to a net benefit of €22m and €65m respectively by 2030. The gains estimated for these two levers are complementary but cannot be added: one of the levers (sometimes both) will be deployed depending on the local situation.
  - Regarding centralised voltage regulation, the technology could be deployed on 200 substations by 2030, with a gain for each substation (if the local situation justifies this solution) of as much as €125k.

Flexibilities are studied as a mean to solve production constraints (active power curtailment) and demand constraints. Regarding demand constraints, the focus was put on the use of flexibility to improve investment planning as well as real time operation and maintenance of public distribution networks.

The active power curtailment of MV production can reduce the amount of power injected by producers during times when distribution networks face constraints related to the insertion of

Benefits and costs of the solutions studied up to 2030



- *Costs: assets, development, curtailed energy …*
- *Benefits: diminution of lost load/curtailement, postponed investments*

production. This solution therefore increases the hosting capacity of existing networks and limits the cost of the insertion of additional renewable production.

Regarding the use of flexibility to solve demand constraints:

- During the real time operation of the network, activating flexibility can **improve the functioning of the network and its operational costs**, both in normal and degraded conditions (during maintenance or incidents). They can be seen as an alternative or an addition to usual solutions, e.g. generators, in situations **that do not economically justify** investments in new infrastructures. Given the low probability that these situations will occur at a given point in the network, these **activations would probably be made in a more opportunistic manner**.
- During the investment planning stage, it is possible to elaborate a strategy regarding the use of flexibility that can **postpone the investment decision while maintaining the quality and continuity of supply** (the residual non-quality is sufficiently reduced to delay the investment decision). The case that is studied concerns the **reinforcement of a transmission substation** that could be pushed back by one or more years thanks to the planned use of flexibility. The integration of the flexibilities and their impacts on real time operation in the investment decision-making process requires extensive studies of the incidents that could affect the substation as well as the operational capacity to activate the flexibility.

To resolve demand constraints, an opportunity-based approach was adopted so as not to make any assumptions regarding the nature of the flexibility sources used to provide the expected service. The economic benefit of the flexibility varies depending on the use case and the local situation that they can resolve. As such, this value can be significant.

Adopting a vision focused on the opportunities of use for flexibility means that no assumptions should be made regarding the nature of the flexibility that could meet such a need. Thus, all the proposed flexibility solutions are considered on an equal basis. For example, a reduction of the demand is considered in the same way as an increase in production.

In terms of value, the approach has been focused on the benefits for society at large that could be enabled by the use of flexibility in the operation of the public distribution network. **The resulting elements are therefore estimates of the maximum collective surplus that could be freed up by the flexibility solutions. These elements are comparable to a maximum cost that society could be willing to pay and under which the activation of flexibility would achieve a new optimum cost/quality ratio in the functioning of the electricity system.** Given the low frequency of power cuts in the network, the activations at a given point in the network would necessarily be rare, which results in a maximum collective 'capacity' surplus of less than €30/kW/year of delay. However, since each of these activations can help customers who have been cut off to resume normal function, the corresponding 'energy' surplus is comparable to the value of the customer's power cut. This then results in a cost equivalent to the value of lost load, i.e. €9,200/MWh for classic incidents and €20,000/MWh for incidents of more than 30 MWh in France.

When the use of flexibility to resolve demand constraints in public distribution networks proves to be economically beneficial for society, mechanisms that make it possible to effectively harness the flexible processes of the installations connected to the networks should be studied.

Some initial trends can be observed:

- The different services that can respond to the needs of distribution network operators can be described using a combination of the following characteristics (different sources of flexibility can potentially be used for a single need depending on the time when the constraint appears):
  - Reliability of the availability commitments: flexibilities that offer even partial availability can be economically viable. However, the announced availability must be reliable because there is no 'plan B' in the event of a failure.
  - Activation delay: short for the management of incidents, longer for other cases of use.
  - Duration of activation: several hours to several days.
  - Frequency of activation: one-off or potentially recurring.
  - Period of use: one day to one year, even several years.
- The contractual framework must be defined. It must be adapted to the local needs and, in certain cases, to the requirement for highly reliable commitments.
- Two systems are possible: over-the-counter agreements and competitive tenders. The terms of remuneration for the services must be defined: depending on the two factors of capacity and energy or, in certain cases, solely on the energy factor, etc.

This study is a key step in the industrialisation of initial smart grid solutions prior to the first large-scale deployments and flexibility experiments provided for in article 199 of the Law regarding the Energy Transition for Green Growth. In addition, other smart grid solutions keep on being developed, particularly for smaller areas and low voltage grids.

The deployment of smart grids requires a step-by-step process: research and development, demonstration and experimentation, industrialisation and deployment.

The functions analysed in this study are in the process of demonstration or industrialisation: **thus, the results presented are one step of the industrialisation of smart grid solutions. This process is being pursued with the first large-scale deployments and flexibility experiments, which are, for the latter, provided for in article 199 of the Law regarding the Energy Transition for Green Growth.**

The functions featured in this study concern the transmission substation and MV network. **Other solutions and potential sources of value are still undergoing evaluation and being developed to respond to the local stakes of the energy transition, including the integration of renewable energy, new electricity uses and electric vehicles to local neighbourhood and thus low voltage grids.**

Appendices

OPERATIONAL PLANNING SYSTEM

DEFINITION

The operational planning system uses forecasting and simulation tools to detect constraints or vulnerabilities in the MV network on different time horizons (from multi-year to multiple times a day). Levers are offered to the operator to remove constraints, minimise losses, improve the security of supply, and maximise the evacuation of distributed generation.

The operational planning system can, among other things, **optimise the planning of works** in a context of strong growth in MV production until 2030. With forecasting and simulation tools, better control can be maintained over the impact on the security of the system, which provides more room for the organisation of works. The operational planning system **thus offers new opportunities regarding the organisation of works so that the amount of curtailed energy can continue to be minimised.**

Exchange platform for coordination with MV producers, RTE and internally within Enedis

COSTS

The implementation of these solutions **does not require the deployment of equipment on the network.**

The cost of monitoring tools is €15m, in addition to the annual cost of corrective and ongoing maintenance.

METHOD

1	Estimate amount of curtailed energy in MWh connected with non-availability due to network maintenance
2	Evaluate the effect on curtailed energy of the optimisation of works through operational planning

GAINS

Operational planning will improve the planning of maintenance works for the networks, with the integration of significant MV production by 2030, thereby **reducing curtailed energy by 10%** with no effect on the duration of the works or on the quality of the maintenance.

The annual savings for the entire grid will vary between €3m and €19m/year by 2030 as a result of the growth of renewable energy, which corresponds to an estimated, cumulated net gain (savings minus costs) for the entire grid of between €62m and €70m. This function will also be essential for the implementation of other advanced functions (centralised voltage regulation and flexibility).

EXTENSION OF SELF-HEALING CAPABILITIES OF THE DISTRIBUTION NETWORK

DEFINITION

The automated mechanisms used to resolve incidents support the people in charge of operating the network in the event of an incident. The fault is located and isolated automatically so that **a reconnection procedure can be carried out rapidly** taking the real configuration into account. They also guarantee the **optimal management of incidents** for a wider variety of network configurations.

Management of transmission substation incidents	Accounting for the lightning strikes	Management of incidents in the presence of producers
Proposed scheme for simplified, automatic reconnection of the lost load	Correlate the lightning strikes and incidents of a zone so that action can be taken more rapidly	Scope of action extends to parts of the network where MV production units are connected

COSTS

The implementation of these solutions **involves communication channels that have already been deployed.**

The estimated cost for the ongoing maintenance of the new network operation tools is €600k for Enedis.

METHOD

Automating the resolution of incidents can reconnect customers more rapidly, thereby **reducing the non-quality connected with incidents in the network**. The reduction in non-quality is measured on the basis of energy not supplied (ENS).

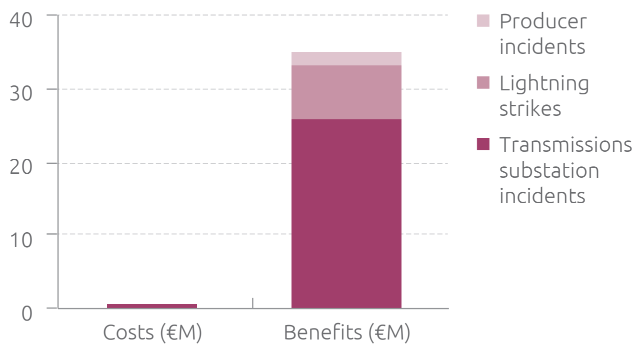
The ENS was evaluated taking into account the average reconnection curve based on the history of incidents from 2011 to 2015 (within the scope of the Enedis operated network).

GAINS

These changes can avoid approximately 360 MWh/year, which corresponds to a **benefit for the entire grid of €3.3m/year and €35m by 2030** (within the scope of the Enedis operated network).

- The management of transmission substation incidents can **reduce the non-quality generated by these incidents by 20%**, and avoid 265 MWh of ENS/year.
- By taking the lightning strikes into account, customers can resume normal function more rapidly by reconnecting the functioning parts of the network. The possible reduction in ENS is estimated to be 85 MWh/year.
- In a context where renewable production connected to MV networks is increasing, the algorithms have been improved in order to resupply the functioning parts of the outgoing MV feeders in the presence of producers.

Costs and benefits of auto-backup



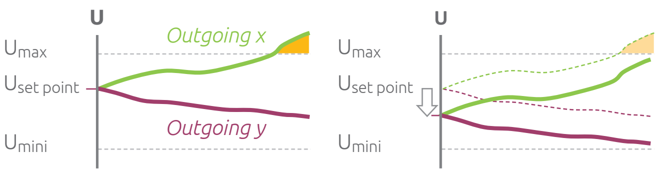
Appendice

CENTRALISED DYNAMIC VOLTAGE CONTROL

DEFINITION

The regulation of the voltage set point at the transmission substation is done dynamically when the voltage values estimated for the network are outside of the contractual voltage ranges. This advanced function can prevent voltage constraints on MV feeders of a single substation that cannot be resolved with a voltage set point fixed for the whole year. In these cases, dynamic regulation reduces the need for works in the network.

Regulation of the voltage set point to a lower level in the event of high-voltage constraints for a MV feeder



COSTS

Implementation requires precise measures, a state estimator and the remote control of the voltage set point value of the HV/MV transformer. The cost of instrumentation for one station is estimated to be approximately €215k. The evolution of the substation's control system to a digital control system is a prior requirement.

METHOD

1	Simulate the arrival of MV and LV production
2	Study the impact on voltage along MV feeders
3	Evaluate the benefit of the advanced function

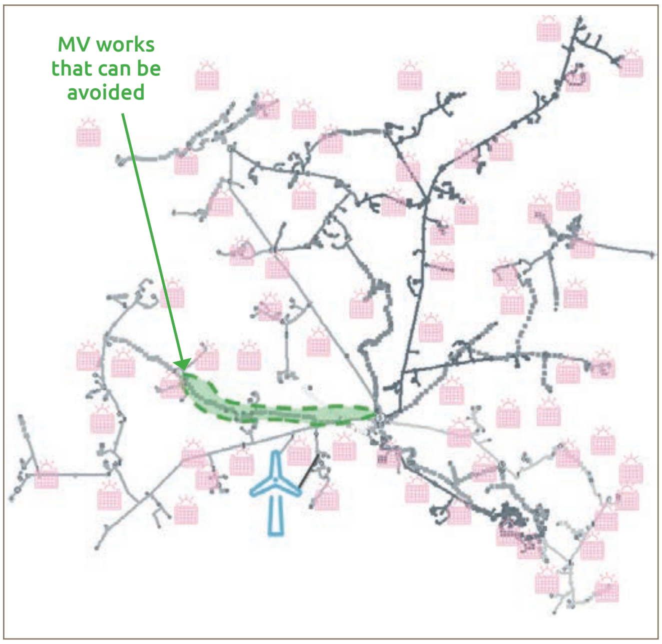
GAINS

The benefit of this solution is highly dependent upon the scenarios of insertion of renewable production. Its **deployment** will therefore be **targeted**.

The **technology could be deployed on around 200 substations by 2030** for three types of constraint.

The **technico-economic benefit** was evaluated for the resolution of low voltage constraints on MV feeders following the insertion of producers and the decrease of the transformer voltage set point to accommodate them, which corresponds to the most mature use case in functional terms. In this case, the **amount of gains expected** for one substation **can be as much as €125k**.

Example of a substation where centralised voltage regulation avoids works



SELF-ADAPTIVE REACTIVE POWER CONTROL BY MV PRODUCERS

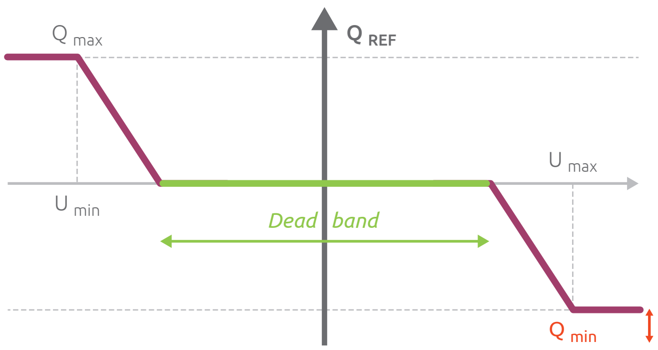
DEFINITION

The self-adaptive reactive power control of distributed generation can enable producers who are connected to an existing outgoing line to go further than the current fixed regulation (referred to as fixed φ tangent) if the constructive capacities of the machines permit it:

- by adjusting the absorption of reactive power in order to **make use of installations during periods of constraint only**.
- by increasing the maximum value of absorption of reactive power (Qmin) in order to **increase the hosting capacity of the existing feeders** while controlling the losses

The installations concerned are medium sized (1~8 MW, i.e. 30% of solar production and 8% of wind production connected by 2030).

Principle of functioning



COSTS

No specific instrumentation is required for the network. On the producer side: an average excess cost of €15k/MW is estimated to increase the maximal level of reactive power absorption (Qmin) when necessary.

METHOD

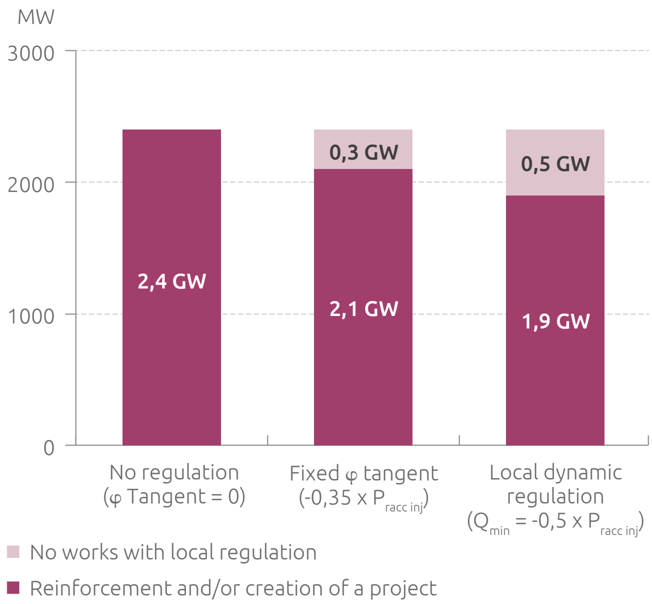
1	Determine the % of feeders under constraint in 2030 with MV producer
2	Analyse the effect of regulation on the %
3	Calculate the annual duration of solicitation of reactive power
4	Estimate the effect on losses

GAINS

The regulation law makes it possible to increase the hosting capacity of the existing MV outgoing lines. For the installations concerned, the gains of this function amount to **€100k/MW**.

At a national level, the study estimates **a net gain of €22m**, which corresponds to the connection of **220 MW** of additional production to the existing outgoing lines. In addition, there is a gain **of €1.5m by 2030** regarding the network losses with the dynamic law (compared with fixed φ tangent regulation). The positive effect on connection costs can result in an increase in the connection of medium-sized installations, which should increase the overall benefit.

Reinforcement needs and/or creation of a project with local regulation and associated costs



ACTIVE POWER CURTAILMENT OF MV PRODUCTION

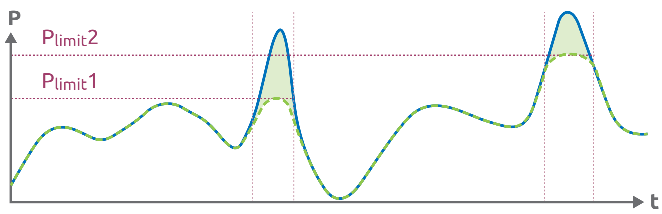
DEFINITION

The active power curtailment of MV production, or the limitation of MV production, consists of limiting the level of injected MV production in order to avoid some voltage or intensity constraints due to the insertion of MV and LV production. **It can limit the need for works and reduce the cost of the insertion of production:**

- **by connecting an MV producer at minimal cost** and/or more rapidly; and/or
- by avoiding constraints on a MV feeder due to **the insertion of LV production.**

The installations concerned are medium sized (1~8 MW, i.e. 30% of solar production and 8% of wind production connected by 2030).

Power curtailment



COSTS

The implementation of the cap on MV production requires precision measurement equipment on the MV feeder in order to monitor the curtailment, estimated at €12k/installation. In addition, the cost of the curtailed energy corresponds to the cost of the substitute energy.

METHOD

1	Determine the % of MV feeders under constraint in 2030 with MV producer
2	Analyse the effect of the function on the %
3	Evaluate the effects in terms of volume of curtailed energy and deduce the gain on insertion costs

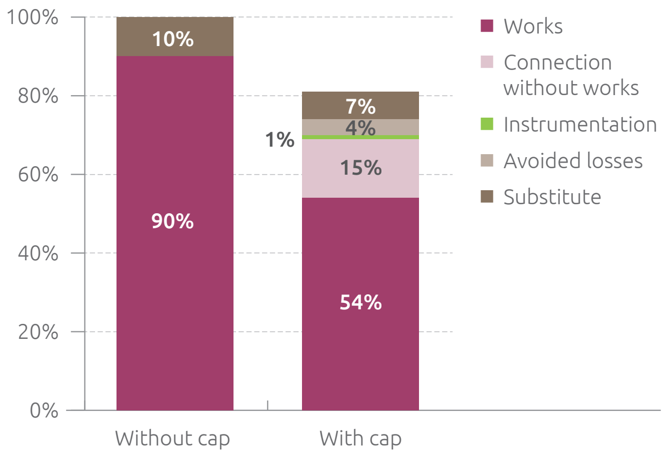
GAINS

By 2030, about 2 GW of medium-sized MV production of 6.2 GW to be connected will be the origin of constraints on the existing feeders (~500 feeders). The cap on production **reduces the cost of the insertion** of production for a significant number of producers **(~ 200 installations)**.

For the installations concerned, the gains for society at large of this function amount to **€90k/MW**.

At a national level, the study estimates **a net gain of €65m**, which corresponds to the connection of **720 MW of additional production to the existing feeders**. The positive effect on connection costs can result in an increase in the connection of medium-sized installations, which should increase the overall benefit.

Cost of insertion of MV and LV production for outgoing lines under constraint without cap



Appendice

USE OF FLEXIBILITY FOR DEMAND CONSTRAINTS

DEFINITION

The study focuses on issues related to the load at the transmission substation and MV network levels.

In certain situations, flexibility sources can enable a better optimum cost/quality ratio by supplementing and/or acting as an alternative to usual solutions

Monitoring/Operation	
1 **Normal operating situation** *(extreme climatic episode)*	■ Use could be foreseen on D-4. Actual mobilisation on D-1/D ■ Activation: several hours. Very low occurrence
2 **Ongoing incident situation**	■ Short incident: little/no prior notice and a few minutes to respond ■ Long incident: the arrival of specific resources can take several hours ■ Activation: several hours. Situation used to plan investments in new infrastructures
3 **Ongoing works situation**	■ Prior notice: minimum 10 days, up to several months. Possibility of creating a provisional programme ■ Activation: duration of works or duration of periods of high consumption during the works

Planning

Once the use of flexibility to manage real time operation is mastered, it is possible to anticipate their use in the investment planning stage.

Taking their impact on non-quality into account during reinforcement studies can make it possible to delay the optimum reinforcement date by one or more years.

IMPLEMENTATION

The forecasting, planning and operating tools of the DSO are necessary to use to flexibility efficiently.

The studies do not prejudge the nature or the source of the flexibility measure. Any solution can be relevant as long its implementation cost for society is lower than than the maximum value displayed below.

A demand constraint can be handled either by decreasing consumption or increasing production.

EVALUATION OF GAINS

Monitoring/Operation	
1 **Normal operating situation** *(extreme climatic episode)* **2** **Ongoing incident situation**	■ Maximum value for society in the event of ongoing incidents of €9,200/MWh. Must be compared with the alternative solutions ■ The frequency of calls will be between 0 and multiple calls per year for each transmission substation
3 **Ongoing works situation**	■ Maximum value for the entire grid of €2,500/MWh. Must be compared with the alternative solutions ■ The potential duration of a call depends on the case and varies between several hours and several days

Planning

Several instance of real investments decisions were studied. For each case, a collective surplus enabled by the use of flexibility, a planned power and a usable duration in terms of a yearly average was computed. A wide range of values was observed for each of these cases.

- Between 0 and 24 €/kW/year OR between 0 and 11,600 €/MWh
- Between 0 and 16 MW
- Between 0 and 186 minutes
- Between 0 and several calls/year per substation

Enedis, l'électricité en réseau

Enedis is a public service company that manages the electricity distribution network. It develops, operates and modernizes the electrical grid and manages the associated data. Enedis carries out customer connections, 24/24 and 7/7 troubleshooting, meter readings and all technical interventions. It is independent of the energy suppliers, which are responsible for the marketing and management of the electricity contract.
Enedis employs 38,000 people and serves 35 million people, that are connected by a low and medium voltage network with a length of one million, four hundred thousand kilometres.

The ADEeF - Association of the Distribution System Operators of Electricity in France

The ADEeF brings together all the French DSOs of electricity operating on the metropolitan interconnected territory to defend their common interests.

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