HOW TO REDUCE THE IMPACT OF MAJOR CLIMATIC EVENTS: ACTION PLAN

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ABSTRACT

Even if "exceptional" incidents are generally excluded from contractual commitments relating to quality of supply, controlling their consequences must remain a major concern for distributors. Indeed, society is becoming less and less tolerant of long and extended power cuts, especially since:
- *Consumers are accustomed to a high level of quality,*
- *The media gives these phenomena coverage which greatly exceeds the areas concerned,*
- *Some studies on climatic changes forecast an increase in the frequency and severity of these "exceptional" events.*

Within the framework of the Public Service Contract signed with the State, EDF Distribution, the main Distribution System Operator in France, carried out an analysis of the system's weaknesses with respect to climatic events of all kinds, and decided on a long-term programme aimed at reducing them. This wide-ranging piece research study comprises several parts, which are presented in this article:
- *Characterization of the climatic phenomena likely to have a significant impact on the continuity of supply, whether relating to the overhead (storms, snow, white frost etc.) or underground network (floods, heat waves etc)*
- *Historical analysis of the impact of these phenomena on French networks*
- *Quasi-exhaustive analysis of the vulnerability of the networks, taking into account their design characteristics, their geographical environment (notably the specific risk for overhead networks in wooded areas) and of local weather statistics.*
- *Characterization of the risk associated with each part of the network, according to its vulnerability, its load and structure*
- *Definition of techno-economic criteria for prioritisation of actions.*

The action plan which was adopted on a national basis following these studies largely consists in laying the most vulnerable parts of the overhead MV lines underground. It also includes actions to reinforce underground networks in urban centres and protect primary substations against the risk of flooding. Its implementation still needs to be detailed at regional level by applying the pre-defined priority criteria.

CONTEXT AND OBJECTIVES

Since the start of the 1980s, the average annual power outage duration has been divided by approximately 8 in France. This has meant that customers have grown accustomed to electricity being available and makes the idea that even an unlikely atmospheric phenomenon could cause a long and massive disruption to the electricity supply of a region, or indeed a large part of the country as was the case in December 1999, all the more unacceptable. This is why on several occasions after a major climatic event EDF has been questioned by the public authorities on how to prevent this from ever happening again. Actions have therefore been undertaken to try to reduce the consequences of similar events.

In this way, following the storms of 1999 EDF stated that should such an event reoccur it aimed to be capable of restoring power to 90% of its affected customers in under 5 days. To achieve this objective, the main actions implemented were:
- The creation of a “Rapid Intervention Force”
- The creation of a stock of generator units
- A programme to progressively reduce the number of HV overhead lines in wooded areas.

Rather than limiting itself to preventing the reoccurrence of a highly improbable event (a storm like the one in December 1999), the Public Service Contract signed in October 2005 proposed a broad approach to the problem of climate-based risks: EDF was asked to try as best as possible to avert the risks of major climatic incidents, regardless of the nature of the phenomenon considered (wind, snow, frost, heat wave, floods etc.). To do this, it first of all had to identify the major risks, then characterize the network's potential weaknesses in light of these risks, and finally define preventive action plans within a reasonable financial framework.

Until then, no such global approach to climatic risks had ever been undertaken. It was especially ambitious since it concerned a network of over 1.2 million kilometres of lines and cables, connecting over 2,000 primary substations, 700,000 MV/LV substations and 30 million customers.

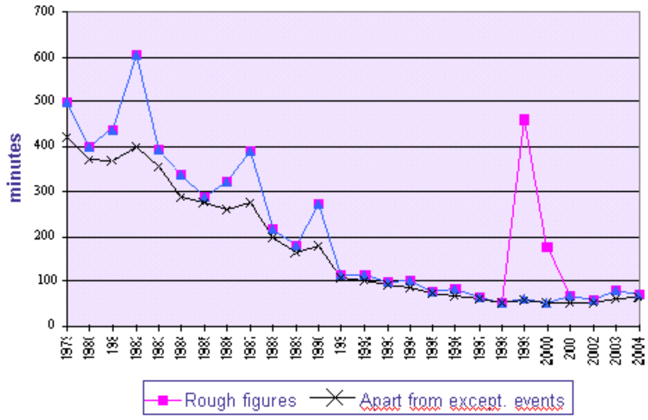
CHARACTERIZATION OF THE PHENOMENA AND IMPACT ON SERVICE QUALITY

A continuum of phenomena, from the everyday incident to the historical catastrophe

What do the climatic events objectively represent with regard to the continuity of supply? The answer to this question is not as simple as it may seem, because we must specify which events are to be considered.

An initial approach is to consider the time series of the System Average Interruption Duration Index (SAIDI). The

SAIDI criteria since 1979



"exceptional events" are generally distinguished from these durations, the definition of which varies from country to country, but they generally correspond to major climatic phenomena.

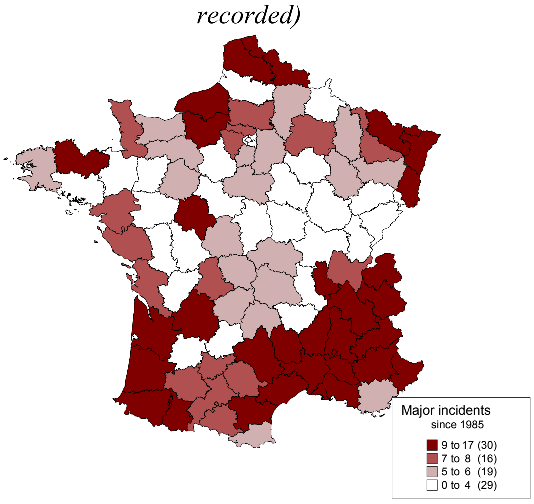
However, events reputed to be "exceptional" do not cover all climatic phenomena. By way of illustration, from the quota of climatic phenomena in all power cuts, the following analysis can be made over the last 10 years:

- Total SAIDI:	64 minutes
- Exceptional events:	7.4 minutes
- Other incidents of climatic origin:	16.7 minutes
- Other incidents and works:	39.9 minutes

Despite this definition problem, we have tried to create a map of the different types of major incidents that have affected France (numbers of events having affected a given *département* for 20 years). By way of example, below is a map of all of the phenomena.

Broad regional disparities can be noted; the analyses based on the type of risk show that a wind risk is especially present in all coastal areas, and that there is a fairly concentrated snow/frost risk in the South-East, South-West and to a lesser extent in Alsace-Lorraine and Normandy.

Map of the major incidents since 1985
(69 major incidents recorded)



The climatic phenomena liable to cause a major incident

For overhead networks, *storms*, falls of *sticking snow* and *frost* were mainly considered. They had three kinds of effects on the network's facilities:

- Direct effect of the wind's pressure on the overhead lines
- Excessive weight of coatings of clogging snow or frost
- Trees falling on the overhead lines (indirect effect of the wind, and potentially of snow or frost)

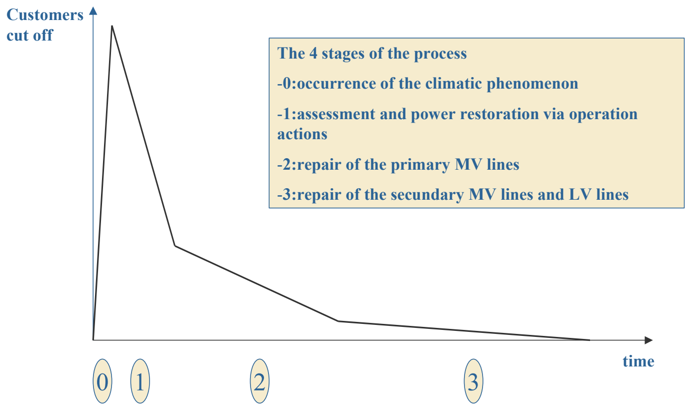
The underground networks are sensitive to periods of *intense heat* ; this reveals itself through a significant increase in breakdowns of the HV cables, leading to a greater number of power cuts, and indeed saturation of the operator's intervention capacities.

Flooding can lead to outages of facilities, mainly primary substations and HV/LV substations.

More locally, risks such as *salt mists* or salt storms can also be taken into consideration in coastal areas as well as *forest fires* mainly in southern regions.

The factors affecting the impact of a climatic phenomenon on the electricity service

Sudden massive climatic phenomena such as storms, clogging snow etc. are dealt with in four distinct stages. Their duration and impact on users' power supplies depend both on the severity of the phenomenon, the characteristics of the network and the operators' intervention capacities. These four stages are shown in the diagram below.



The envisaged protection actions have varying effects on the duration of each of the stages, and on the number of customers that remain without power. For example, increasing the human and material resources available in the event of an incident would shorten stages 2 and 3. Reinforcing the weakest secondary networks would reduce the duration of each of the stages and the power cut off more or less proportionally to the quantity of network reinforced. Making the primary lines less sensitive would have a more limited effect on the total power restoration duration, but a massive effect on the duration of stages 1 and 2 and the power remaining cut off during these stages.

Given the current state of our networks, efforts already made in terms of operating methods and our desire to reduce the media impact of the incidents, solutions that allow us to reduce the number of customers remaining without power at the end of stage 1 (and the duration of this stage) are where our priorities lie.

THE ASSESSMENT OF THE NETWORKS

The risks linked to the MV overhead networks

Facilities deemed vulnerable: In our analysis, we considered to be vulnerable any section of the network which is in one of the following situations:

- In a wooded area
- Having constructive features which do not guarantee that it will resist wind pressure or an overload of snow or frost which risks occurring at least once every 20 years.

The analysis was carried out exhaustively on all of the networks by gathering together information from our technical databases, maps of wooded areas (made by satellites) and weather charts providing per 100 km^2 of surface area, the wind speeds and snow or frost overloads which risk occurring once every 20 years.

Each section can thus be allocated risk coefficients λ , with a value of 0 for a section situated outside wooded areas and designed to resist the abovementioned events, and higher the greater the risk of not being able to resist these events.

For all the MV networks operated by EDF Réseau Distribution (587,000 km, including 370,000 overhead networks), the analysis has therefore highlighted those which have a (low or established) risk by distinguishing the primary and secondary lines.

Overall characterization of the risk for a given area

For a section with an inherent risk λ, of a length *l* and supplying n customers, its contribution to the risk takes the form:

$$R = \lambda . l . n$$

For an entire outgoing MV line or given area, or even for the whole of France, the overall risk takes the form:

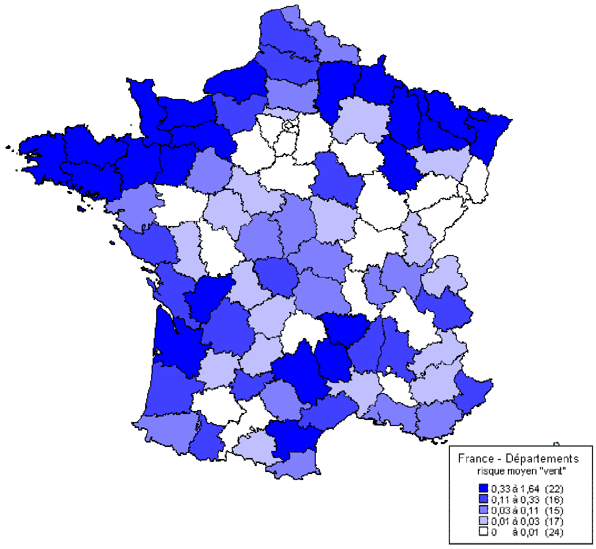
$$R = \Sigma(\lambda . l . n).$$

Reduced down to a customer within the area considered, the average risk is expressed by:

$$r = \frac{\sum(\lambda . l . n)}{N}$$

(N being the total number of customers within the area).

The average risk coefficient r is therefore consistent with a length: it corresponds to the average length of the network that is "at risk" (weighted by the coefficients λ) contributing to the power supply of the "average" customer in the area considered. For the current French networks, it is in the region of 0.46 km (including 0.26 for the "falling tree" risk, 0.09 for the "wind" risk and 0.11 for the "snow/frost" risk. A map of the lengths of weak networks and average risk coefficients has therefore been drawn up for each of these risks. An example is provided below:



Example: map of the wind risk per *département*

The "intense heat" risk

Studies that have been carried out, particularly following the 2003 summer heat wave have distinguished two phenomena:

- Breakdowns of accessories (particularly joint boxes between cables of different technologies), which occur mainly at the time of temperature increases
- A reduction in the load-flow capacity of the cables themselves, combined with the warming up of the underground due to a prolonged period of intense heat.

The first phenomenon should be dealt with both by an appropriate maintenance/replacement policy, as part of the operator's "normal" commission, and if necessary by making special breakdown resources available. The second is more specific to periods of heat waves, and was thoroughly analysed during this study: based on the work carried out by EDF R&D department quantifying the reduction in load-flow capacity of the various types of cables, we tried to identify outgoing sections that are "at risk".

Several hundred kilometres of HV cables, generally in large urban centres, have therefore been able to be characterized as "at risk", given the loads they must convey, in the short or medium term.

The risk of flooding

In the event of flooding, it is mainly primary substations, MV/LV substations and the networks' operating equipment that can be affected. The resulting power supply interruption affects customers situated in flood plains and those supplied by facilities situated in flood plains (even if they are not directly flooded). We have basically attempted to determine a list of facilities situated in flood plains.

This work is difficult since we do not have common and consistent references on this risk like we do for wind and snow. Some particularly sensitive regions have already carried out in-depth analyses and devised action plans (e.g. Paris, using the catastrophic floods of the Seine in 1910 as a reference). For others the evaluations are still underway.

THE ACTION PLANS

Protecting the MV overhead networks

The general actions planned: To reduce the risks affecting rural MV networks, those with outages that have the greatest impact need to be reinforced or buried first, as part of a long-term coherent structure taking the direct reliability of the networks' elements and their contribution to an optimized operational plan into account.
The amount of network it will be possible to "deal with" within a given budget clearly depends on the technique chosen. In most cases, it will involve building underground networks to replace the weak networks. Wherever possible and economically relevant, other solutions will be envisaged such as extensive maintenance, overhead mechanical reinforcement, felling and replanting of trees etc.

Choosing a strategy and prioritizing the actions: Not all of the networks with "weaknesses" can be dealt with in the medium term. Different strategies have therefore been simulated so that the one with the best risk reduction/cost ratio can be chosen. These studies show that the primary lines with an "established" risk should take priority, and the other sections of the network should be collated according to the criterion $R/C = \Sigma(\lambda.l.n)/C$, where R is the risk calculated above, and C the cost of the investment.
By dealing with less than 10% of the HV overhead networks (which still represents 35,000 km of network to be dealt with on a national level), the study shows that a gain of almost 80% on the average risk r level can be obtained. Let us not forget, however, that reducing the risk does not mean that customers will not suffer from power cuts in the event of a major climatic phenomenon (this is not the priority we have chosen), but their power may be restored quickly, after the assessment and operations stage.

The LV overhead networks

The LV overhead networks are divided into two categories:
- The networks of pre-assembled (or "twisted") conductors whose mechanical performance does not cause a problem and which are adapted to quick power restoration
- The networks of bare copper conductors, more sensitive to the impacts of vegetation (tangled conductors, ruptures etc.). There remain around 120,000 km which are very gradually being cleared. The weakness of the overhead networks mainly concerns the thin section conductors largely present in rural areas. Protecting these networks requires gradually replacing them with a twisted network, and more rarely with underground systems.

The objective analyses concerning the priority to be given to this type of operation in relation to protecting the MV networks clearly conclude that MV is the priority, in view of the overall effectiveness of the actions.
In the short term, protecting the LV networks will mainly aim to ensure quick power restoration, after a major climatic event, to sites accessible to the population which will have been previously identified together with the local authorities.

The MV underground networks and the "intensive heat" risk

The at-risk MV underground cables of old technological design clearly need to be replaced.
For the others, re-balancing of the loads can be envisaged by adopting a "heat wave" operational plan based on sections of synthetic cables.
The relatively small quantity of networks reported to be "at risk" should allow us to deal with them thoroughly.

The risk of flooding

There are very varied approaches to this issue. A primary substation in which only the underground is liable to flooding cannot be dealt with in the same way as a primary substation with open cells, a primary substation with compact cells or a source substation that is liable to total flooding. The primary substations potentially threatened by flooding must therefore be analysed on a case-by-case basis, which should, depending on the case, result in decisions regarding:
- Measures to protect the substation (barriers, pumps etc.)
- In a very small number of cases, extensive investment in transfers or raising
- Restructuring of the MV network to allow power to be restored to non-flooded areas from neighbouring substations.

All of this work should lead to the set up of a more specific programme in 2007 to reduce sensitivity to the risk of flooding.