How new digital technology contributes to the maintenance and operation of ÉdF's nuclear fleet

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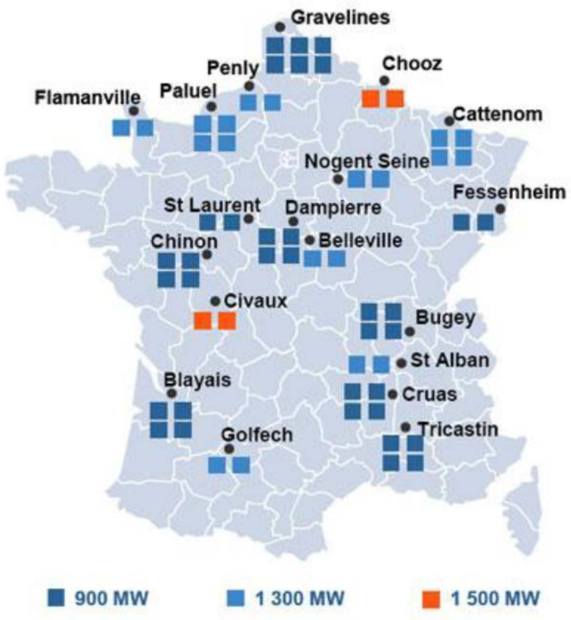
Abstract:
The French national electricity company (ÉdF) has a fleet of operational nuclear power stations that counts 58 reactors built in standardized stages and, on the average, 32 years old. It also has a legacy of abundant, diverse data that could be processed using new techniques in data analytics that are part of the big data bang. Following a phase for demonstrating these techniques, ÉdF is putting to general use both the tools of data analytics and the procedures for improving the company's data legacy. This combination is a lever for improving the safety, operations and maintenance of this fleet of nuclear reactors.

ÉdF's nuclear power stations

From the start, a few points of background information should be made about the fleet of nuclear power stations for generating electricity that are run by ÉdF in France. This fleet counts 58 reactors that use the same technology (pressurized water reactors) descending from the PWRs designed in the United States. The average age of the reactors is 32. The decision, under the French electronuclear program, to build most of these reactors was made following the oil shock in 1973. For reasons of productivity, these reactors were designed in series called "pallets" (Figure 1). Reactors in the same series have a standardized design and choice of materials. In other words, identical materials have been used in several reactors. Since a coherent model of the data describing installations was adopted from the start, comparisons between reactors are not only possible but are very pertinent for optimizing the performance of operations.[1]

[1] This article, including any quotations from French sources, has been translated from French by Noal Mellott (Omaha Beach, France).

Figure 1: France's fleet of nuclear power stations operated by ÉdF (©ÉdF)



Another point to make has to do with the safety requirements for running nuclear power plants. They come into play at several levels: the choice of design, directions for operating the plants and, too, management's implication. The keystone to managing safety is feedback. Every event that happens has to be methodically analyzed to keep it from happening again. This requirement implies storing all data during all phases in the life cycle of these 58 reactors: design, construction, operation and dismantlement.

Another point to bear in mind is that this fleet's performance is partly linked to the operator's ability to optimize the volume of maintenance, which has a direct impact on how long the reactors will be out of service for repairs.

A consequence of the context just described is that the nuclear fleet has a huge legacy of structured, available data that lends itself to the nascent data analytics. In concrete terms, these new techniques enable us to analyze examples or use cases, as described hereafter. Such analyses used to demand strenuous efforts in order to collect and consolidate historical data from distinct sources about the problem to be analyzed.

It is worthwhile pointing out that such analyses have been made much easier since ÉdF set up a "big data infrastructure" for storing and processing masses of diverse data. The management of ÉdF's nuclear fleet decided to invest in this sort of infrastructure in 2015. By the end of this program, ÉdF will have, for optimizing operations, a data lake (of a Hadoop type) containing a wide variety of numerical and textual data, structured or unstructured. These data will, in the main, be:

- data on processes: time series from sensors placed in installations (pressure, temperature, flow rates, vibrations, etc.), readings from meters during inspection rounds, records on the chemical and radiological monitoring of circuits; and
- data on the context from: the computerized maintenance management system (CMMS), databases on the analysis of events during operations, and enterprise application software for planning and registration (*i.e.*, registering a chronological series of indispensable regulatory operations on the installations for the purpose of the safety and security of the personnel during interventions).

Use cases

One use might seem trivial at first sight, namely visualizing the data. The foremost need shared by all users is for the huge volumes of data to be aggregated clearly, intelligibly and rapidly thanks to effective visualization tools. New tools allow for easily viewing quite diverse data. This improves the reactions of the persons in charge of supervising and diagnosing the state of components and materials. When a change in a material's operational parameters is detected, this type of tool provides the persons in charge with a consolidated view of: the forces (or load) involved, past maintenance operations and feedback with information on comparable changes in similar materials in the fleet.

A second use is related to transitory phases in operations, when an installation is brought from one baseline condition (characterized by stable physical variables) to another. Controlling these transient states is a major issue for operators. A transient state is a phase of operations that increases the probability of passing a threshold of protection, the most dreaded threshold being "automatically stop reactor". Since passing this threshold stops the reactor very fast, it potentially has serious drawbacks for safety and production. Furthermore, since transient states put materials under stress and, therefore, affect their life cycles, checks are performed, for example, on circuits subject to pressure. These circuits have been designed to hold up, once in service, under certain conditions of pressure and temperature corresponding to a mechanical load. Once placed in operation however, they have to be checked to see whether these conditions are compatible with the conditions occurring during a transient state. Optimizing an installation's operation by taking account of the life cycle of materials as well as safety and security conditions entails, therefore, an *ex post facto* analysis of transient states. This has been made much easier with the help of the tools provided by data analytics, which enable us to rapidly examine huge volumes of data on processes so as to identify transient conditions.

A third use is for the predictive maintenance of materials. Given economic exigencies, this sort of maintenance entails foreseeing the degradation of materials so as to optimally plan maintenance interventions before the materials become defective. When there is ample feedback about the material and certain defective conditions have been observed, a statistical study can predict the material's reliability. For this sort of study, data have to have already been collected, preprocessed and formatted. For a long time, doing this was a stickler that kept operators from pursuing this approach. Here too, as a few use cases have shown, data analytics makes it much easier to undertake this sort of study. Thanks to the ease of crossing data from different databases, this approach allows for making reliability predictions that take account of factors related to a material's actual uses: operating time, maneuvers for placing it in operation or taking it out of operation, chemical characteristics of the fluid circulating in it, etc. Thanks to the widespread deployment of these methods, preventive maintenance programs can be more frequently updated by planning maintenance operations on materials as a function of their use.

Given that the nuclear fleet is engaged in an unprecedented program for prolonging the operation of its reactors beyond forty years, data analytics will help optimize plans for replacing major components by establishing priorities; this will generate savings.

The aforementioned uses of data analytics are but a few of the ways imagined to benefit from the legacy of data on the nuclear fleet. Prospects also exist in other chains of production. To grasp these opportunities, ÉdF is equipping all its production channels with an across-the-board "factory data analytics for production", which has come out of the ideas proposed by the information system and the divisions in charge of production processes and of R&D. This factory data analytics will assemble the technical and human means for accelerating the passage from design to actual application in the field. For ÉdF's production units, it will pool the tools, methods and uses related to data analytics in order to capitalize on them.

Techniques of data analytics

What techniques of data analytics are being put to use?

The data coming from sensors in real time are leading to the processing of huge volumes on data from time series. This is useful for keeping a record on the operational situations that are detrimental to a given material or for classifying the modes of a material's performance by analyzing the past.

Processing the vast quantity of records on interventions from the CMMS and from the databases on feedback entails using techniques for processing natural language. These techniques, also known as "text mining", help pull structured information out of the reports and records that various persons have made when filling in forms containing free-text fields (*e.g.*, about the frequency of replacing a worn-out part). This information is useful for studies on reliability.

More advanced techniques are under study for improving the nuclear fleet's remote electronic monitoring systems, which are based on comparing in real time parameters on a material's state with operational situations that are known or that have come out of machine learning. These monitoring systems thus enable us to detect anomalies ahead of time, before defects appear in a material in use. The targeted improvements are to provide (once an anomaly has been detected and nearly in real time) a diagnosis, prognosis and assisted decision-making. One path being explored to achieve this involves innovative algorithms for processing masses of heterogenous data. Another path is to couple data with the physical modeling of components so as to foresee (when the data on the defect are not very numerous) the evolution of the anomaly and, therefore, the material's remaining serviceable life.

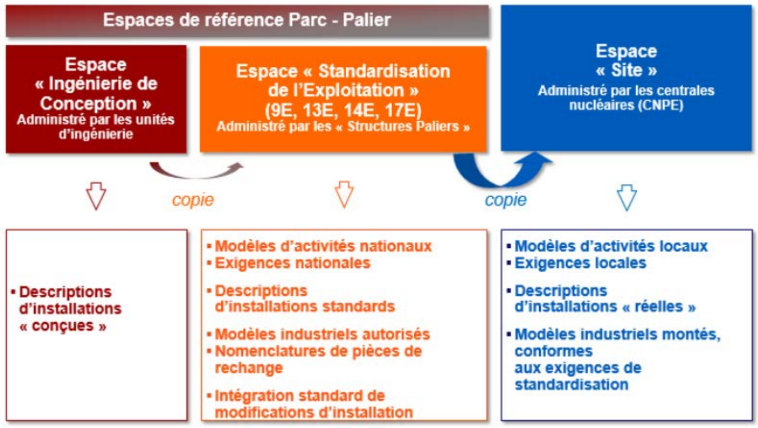
Finally, data lakes open the possibility of using deep neural networks to make a model of complex phenomena for which the engineering sciences have not proposed satisfactory solutions. Several studies of this sort are being conducted.

Legacy data

As already explained, the processing of data with these nascent techniques will enable ÉdF's nuclear fleet to make significant gains in performance. However this should not keep us from seeing the efforts needed to increase and improve the inherent potential of the firm's "legacy data". This is a major concern for operators of nuclear power plants. To illustrate this, let us look at two major programs for making improvements.

The first program, now terminated, concentrated on structuring legacy data. Although, as stated, the fleet of nuclear reactors was built in series (pallets), ÉdF did not benefit fully from this standardization because the CMMS used till 2010 did not take account of the fleet or pallet effect. For instance, any changes in operating specifications had to be made separately, at the level of each power station's information system. This problem was solved during the SdIN program in 2009 for renovating the information system. In concrete terms, operational modifications were made in the asset management software package to take account of this characteristic of the fleet. Benchmark data by pallet were created: the models of the installed materials and equipment, of requirements and of operations. Finally, specific structures for governance and for updating these data were adopted for each pallet. Figure 2 depicts the structure of the "information spaces" retained in the CMMS.

Figure 2: Data spaces in the computerized maintenance management system (CMMS) of ÉdF's nuclear installations (©ÉdF)



The second program, now under way, focuses on digitization and the collection of data as close as possible to the field. Thanks to the invention of tablets, an electronic record of interventions ("e-DRT": *dossier de réalisation de travaux électroniques*) is now used in the field for maintenance and other operations (*cf*. figure 3). Experiments are now being carried out in five of the nineteen locations of nuclear reactors. Much work must be done to electronically format the procedures for interventions. Among its many advantages:

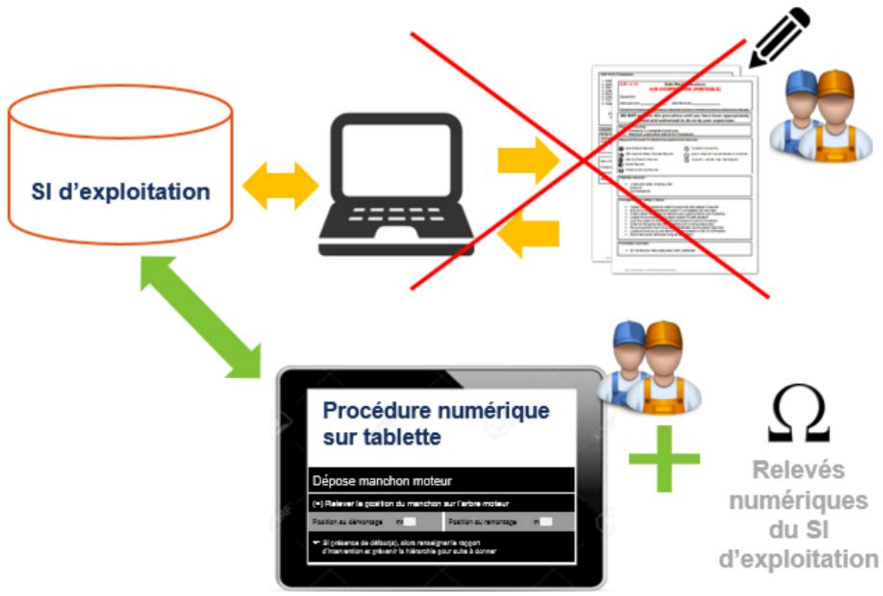
● a simplification of the tasks of the maintenance team during interventions thanks to more intelligible records (gains in maintenance and, thus, safety);

● an improvement of the "hard" time (the time devoted exclusively to the actual gestures performed during maintenance interventions) thanks to on-line assistance via tablets in cases of unforeseen events during maintenance, and real-time monitoring thanks to the reading of meters, the photos taken, etc.;

● no need to re-enter the data gleaned in the field, hence a simplification of procedures for archiving records; and

● more responsive communications about how the intervention is proceeding from the field to the control team, which coordinates all maintenance operations carried out while the reactor is out of operation (productivity gains owing to an optimized sequencing of operations).

Figure 3: Electronic records for planning and conducting interventions (©ÉdF)



Conclusion

ÉdF's nuclear fleet comprises 58 operating reactors that were built in standardized series (pallets). There is a rich legacy of data that lends itself to the new techniques of data analytics, which have arisen with the advent of big data. Following a phase for demonstrating the interest of these techniques, the tools of data analytics and the procedures for improving legacy data, as they are being rolled out, provide leverage for dealing with two major issues in the French nuclear industry: safety and the improved performance of operations and maintenance.