HEALTH INDEX : A TECHNICAL INDICATOR OF UNDERGROUND NETWORK RELIABILITY

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ABSTRACT

As the French underground network gets older, new methods are developed in order to classify links with respect to their life expectancy and to prevent outages. Among them, the Health Index is a macroscopic tool taking into account many parameters to evaluate the breakdown risk for a link. Thus, links of a same grid can be ranked. A preliminary study has been done in south-east of Paris in 2009. This confirmed that risks of failures are not only given by patrimonial data; taking into account environmental data is important to get a good accuracy of a grid health.

INTRODUCTION

French underground network is getting older. To prevent breakdowns and to rank links according to their failure risks, a new asset management tool has been designed. This tool, named "Health Index", is based on several mechanisms of degradation. Its design allows estimating restraints existing in the field, and potential consequences on the underground network reliability.

In this article, we will explain the Health Index method, regarding the global context of ageing on the French grid. Then, needed data will be presented, in order to focus on mechanisms and show how difficult it can be to collect them. At last, a case study will be exposed : application of "Health Index" has been done on the south-east of Paris, then on a small suburban town.

CONTEXT : A WORRYING AGEING

An important proportion of transmission and distribution underground network is older than thirty years. Before synthetic cables and accessories were installed, different technologies were developed, all of them using paper insulation. Little by little, these technologies are replaced by synthetic links. However, we have to notice that first generations of synthetic cables, installed between 1978 and 1981, experienced some breakdowns, due to concerns overcome since. Today, there are 230,000 km of underground cables, including 30,000 km of paper-insulated cables.

Feedbacks show that some populations of cables and accessories know an increasing number of outages. These outages are sometimes hard to explain precisely, because several parameters have an impact on life expectancy. These parameters are related to thermal issues, as well as electrical or mechanical issues. In addition, service conditions have changed : links installed thirty years ago may have more solicitations today, because of urban expansion.

For all these reasons, ageing anticipation is needed : the failure rate is growing, but a renewal can not be done only for age issue. In conclusion, a progressive renewal has to be done, ensuring the continuity of distribution duty in any case (asset management). This means we have to know which links have to be changed first, with a tool giving priority, a tool based on our knowledge of underground network and its mechanisms of degradation : here comes the Health Index or HI.

GENERAL PRINCIPLE OF THE HI

Stricto sensu, the Health Index is a number (from 0 to 1) giving a probability of breakdown for a given system (cable, link, network…). It permits to compare several items in order to give a relative evaluation of their level of ageing. Once the ranking done, decisions can be taken to focus investments. *Lato sensu*, the Health Index is the tool which permits to calculate this probability.

For underground links, the tool considers four mechanisms of degradation :

- Electrical ageing of the cable,
- Thermal ageing of the cable,
- Mechanical ageing of the cable,
- Global ageing of accessories.

For each mechanism, ageing law follows a Weibull distribution permitting to evaluate the level of deterioration related to the mechanism. Then, every mechanism is weighted, according to its importance in the global mechanism of degradation. In the end, we get the following formula :

$$HI = \Sigma [Wfi \times Ifi]$$

where Ifi is the grading (level of ageing for a given mechanism) and Wfi the weight associated to this same given mechanism.

At the beginning of a study, all Wf are taken equal to 0.25. When the feedback is precise enough, we can compare it to our result and change these weights in order to get a more accurate model.

MANY DATA NEEDED

In order to take into account each mechanism of degradation through an ageing law, several data about cables and accessories have to be collected. Some of them are quite easy to get, but if we want to have an accurate estimation we need to go further, and collect data that are more difficult to find. We can define three kinds of data.

Patrimonial data

These parameters are, for most of them, easy to get as they can be found in existing databases. They are related to cables and accessories characteristics : length, technology, age, conductor, section, installation, etc… However, we can notice that accessories databases don't permit to know where are cold-shrink joint, heat-shrinking joint, etc. At best, we can get the age of these accessories, and whether they are used for transition between synthetic and paper-insulated cables.

Service condition data

To know how a network gets older, we have to know how it has been used, and operated. Indeed, it's not really easy to detect if a link has been often overloaded, but these data bring many important information. Beyond load, it is useful to know if there has been many short-circuits, many load fluctuations or if the link has been installed with important bending, etc.

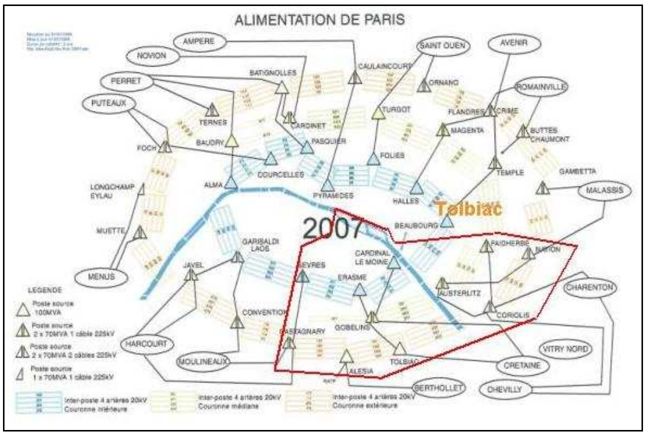
Environmental data

Beyond the link and the way it is operated, it is very important to know the environmental condition of the system. Indeed, outages often come from the outside, though many factors of degradation can surrender our network. Among others, we can underline thermal proximities (with heating pipes), electrical proximities (with other links), corrosive soils, stray currents, slopes which lead to impregnant migration in paper-insulated cables, etc. These environmental data are difficult to collect, but we will see new technologies that can help crossing network and geographic data.

As we see, many parameters are taken into account in the Health Index (about forty). Among them, some are easy to get -patrimonial data- but most of them need research. However, it is the condition to have a good estimation of the outage probability : the more accurate data are, the more accurate results can be.

CASE STUDY : PARIS NETWORK

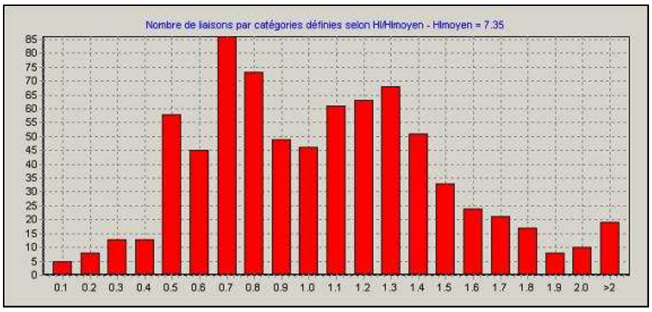
First applications of the Health Index dealt with HV network, and particularly with high-pressure fluid filled links (2005). Then, application on a MV network was performed on a grid close to London (2007), before making the first experiment on a French MV underground network : Tolbiac operating agency, which manages South-East quarter of Paris.



Paris network (Tolbiac agency is in red)

This area contains about 1,300 km of underground MV links (20 kV), fed by eleven substations (225/20 kV). Patrimonial data were quite easy to get, at last for cables, as we collect them with a geospatial tool called Mercator. This tool shows asset belonging to EDF, in particular the route of underground network. That is how we get information about ages, lengths, conductors etc. of these cables.

In order to get a more accurate result with the Health Index, we decided to study three environmental risks : thermal proximities, sloped paper-cables, and humidity of the soil. Naturally, to make it, we had to collect data about slopes, route of the hot water pipes and places where water can be more present. In the end, this long work was useful especially for the two first risks. As regards humidity risk, we concluded that moisture level in the soil is high enough to be harmful, even if it is far from a river.



Results of HI applied on Tolbiac agency

On the final results, we see HI level in abscissa (divided by the mean value which is, here, 7.35%), and the number of links concerned in ordinates. This comparison permits to ranks links according to their degradation level. Synthetic links are mostly on the left side with a good health, while links with paper-insulated cables are mostly on the right.

If we separate these two technologies, we have a 5.35% mean value for synthetic links, and 9.76% for links with paper-insulated cables, which confirms our observation. Now, we have to take feedback into account, and see whether hypotheses are realistic.

FEEDBACK AND LIKELIHOOD MAXIMUM CALCULATION

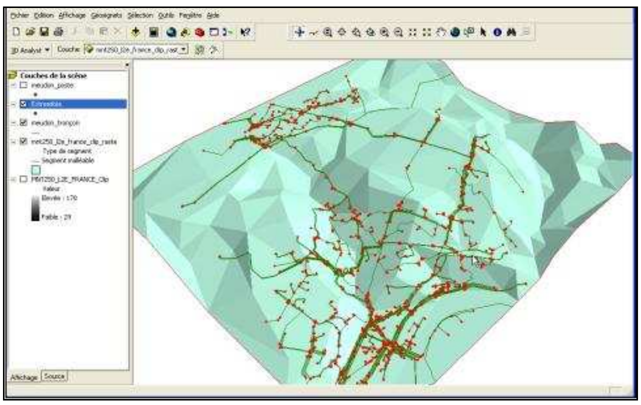
It was important, once result given, to control it with a view of real outages that happened on the field. This crucial data was quite complicated to get, but thanks to paper register kept in Tolbiac agency, we had a feedback from 2000 to 2008 which gave a good vision of these failures. In particular, we saw that sloped paper-insulated cables seemed to have more failures than others, which confirmed the risk we supposed to exist on the field.

On another hand, we had to see whether our hypotheses upon the failure rate was realistic. A statistical study on our failures feedback has been performed with a likelihood maximum calculation. It led to a failure rate of 1.71 10^{-2}/km/year for cables, and 5.14 10^{-3}/accessory/year. Our initial hypotheses on weighting factors lead to 1 10^{-2}/km/year for cables and 3.75 10^{-3}/accessory/year, which finally appeared to be not so bad estimates.

FOLLOWING STUDIES AND PROSPECTS

These encouraging results led us to make the same study on another area : the town of Meudon, in the south of Paris. A location where many sloped paper-insulated cables can be found. This statement let us think that a possibility to confirm this risk existed there. Unfortunately, this area isn't wide enough to show a sufficient feedback and validate our results, and the manual collect takes a long time, looking for contour lines to estimates the declivity of a link. However, it was a good opportunity to test our model once again, and to go further in the collect of information.

In particular, a more automatized way to collect data has been found, in order to get faster methods. Using a new geomatic tool, we are now able to superpose the tracing of underground network with data about altitude.



A new tool to get environmental data

We can easily imagine to use this software to get quickly information about sloped cables, but also thermal and electrical proximities, bending rays, etc. A new study on Tolbiac agency, foreseen for 2011, will be a good way to apply this method, and make our Health Index model more accurate. In addition, a fitting has to be done in order to adjust the feedback loop and improve the grading of accessories ageing using more detailed accessories data.

CONCLUSION

The Health Index is a technical tool for asset management, allowing to range links in a network, in order to give priorities in investments. Lying on four Weibull's laws fitting with four mechanisms of degradation (electrical, thermal, mechanical and related to accessories) and weighted by value corrected in a feedback loop, Health Index permits to estimate the failure probability of each link.

A first experiment on a French MV underground grid has been carried out on Tolbiac agency, in the South-East of Paris. In spite of the difficulty to collect data entry, we finally got information about patrimonial data and some environmental data. It was a good way to show how important these data are : the more accurate they are, the more accurate results will be. Feedback and likelihood maximum calculation permit to be confident about this model. In addition, a particular risk has been confirmed : sloped paper-insulated cables. That is why a new study has been realised on Meudon, unfortunately a too tight area. Nevertheless, we finally found a good way to collect data more easily : a geomatic tool allowing to fit network route with environmental data, and which could be used in 2011 to feed Health Index tool.