Study Committee A3

Transmission and Distribution Equipment

Paper 10844_2022

Risk based replacement policy for RTE’s Instrument Transformer (IT)

Mandana TALEB *, Sami TAZI, Laura COHEN, Xavier GILLES, Benoît IZAC

RTE

France

Context

RTE’s current replacement policy is established based on:
1. The PCB pollution
2. The risk of failure during high temperature seasons
3. Mainly the age of the Instrument Transformers

RTE wishes to anticipate the response to new challenges: on the one hand, the CRE's request for the establishment of auditable policies, and on the other hand, the desire to have a common “risk-based" method to build the various asset management strategies. The “risk-based" methodology relies on a 5 steps risk analysis:

1. Identification of a decision problem
2. Identification of the related hazardous event
3. Characterization of the likelihood of the event
4. Consequence analysis
5. Search for the optimal solution

Here the objective is to apply this method to a risk management strategy based on preventive replacement. It allows a framework for making and implementing decisions that seek an optimal **balance between the performance, costs and risks** associated with the use of assets to achieve an organisation's strategic objectives.

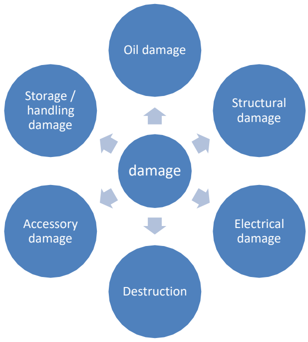
1. Identification of the decision problem

The decision problem in our study is to find **the optimal age of preventive replacement of each category of IT** in order to control the risk associated with equipment subject to failure with damaging consequences.

2. Definition of the hazardous event

One of the primary tasks in this study is the qualification of **hazardous events** which is characterized by the failure of the equipment or out of range of the CVT's qualified precision.

Collecting the relevant data has required a real archaeology of the data. For each piece of equipment in operation over **2010-2020,** the target database must present exactly one observation:

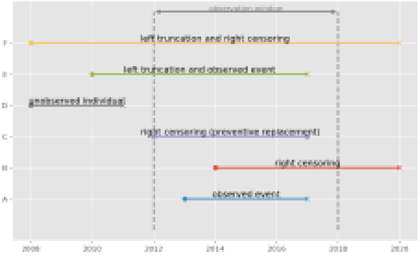


3. Data collection

3.1. Structuring data for risk analysis

The likelihood of failure is the probability distribution of time between the installation of the equipment on the network and its hazardous event failure. It is therefore necessary to determine the date of commissioning of each asset and its current state. This information is at the heart of the survival analysis and must be as precise as possible.

Data collection needs to be carried out rigorously, in particular to take into account possible censoring and truncation biases.



IT	Entry	Time	Event
A	0	4	1
B	0	4	0
C	0	5	0
D	Not in DB	Not in DB	Not in DB
E	2	7	1
F	4	10	0

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3.2. Database for instrument transformers

To obtain the information needed for the study, several difficulties had to be overcome: **multiple sources, multiplicity of formats, heterogeneity of data, access to data**, etc.

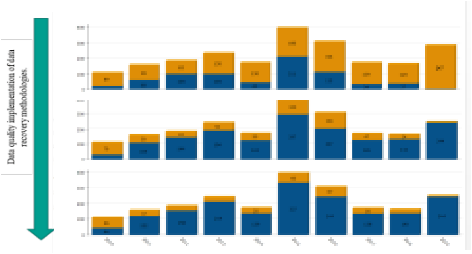

Figure 1.Assessment of missing data and implementation of data recovery methodologies (blue: known data, orange: unknown data).

4. Definition of the three variables for the survival analysis

The key point for data archeology is finding the evolution of the status of the asset (reception on site, commissioning, uncommissioning…) and the association of this change with an event on the network.

The basic database for the study needs to give, for each asset: its age at the start ('entry') and at the end ('time') of its observation period, and its status, i.e. failed, replaced or in use ('event').

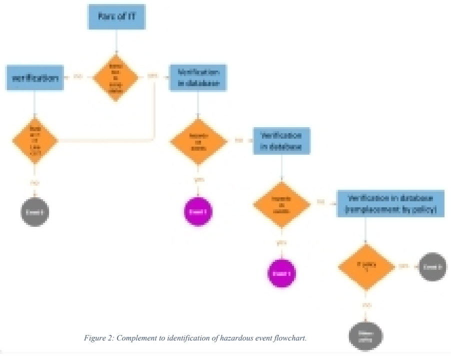

Figure 2: Complement to identification of hazardous event flowchart.

The database contains all the damage reported to RTE as well as the background elements necessary for their understanding and resolution. This database has been improved and it now includes all IT information since 2010.

5.Survival analysis on the combined transformers

5.1.Survival function

Characterizing the likelihood of the event consists in defining the probability distribution of the time between the installation of the equipment on the network and the hazardous event, and its parameters.

$S(t;\lambda)=e^{-\lambda t}$ (1) Exponential law

$S(t;\alpha,\lambda)=e^{-(\lambda t)^{\alpha}}$ (2) Weibull law

$S(t;\alpha,\lambda)=e(-\alpha(e^{\lambda t}-1))$ (3) Gompertz law

Those parametric distributions are fitted to the data. A graphical comparison with the non-parametric estimator of the survival function allows for a first validation of the chosen model. The AIC criteria is used to confirm the selection.

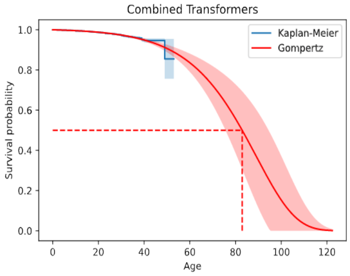

Figure 3: survival function for combined transformers (without the EJ33 model). The red dashed lines indicate the age at which half of the assets experienced their hazardous event.

On occasions, the non parametric estimator shows multiple inflection points, a feature which can characterize multiple ageing process within the population. The study can then be followed with an exploration of potential covariates.

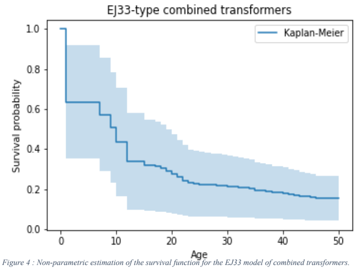

Figure 4 : Non-parametric estimation of the survival function for the EJ33 model of combined transformers.

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5.2.Covariates

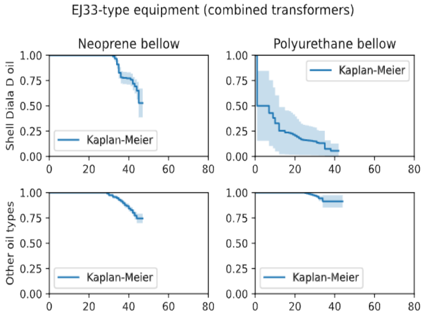

Figure 5: Kaplan-Meier curves for Combined Transformer (EJ33) taking the covariates into account.

6.Identification and evaluation of the consequences of failure

All the consequences of a failure must be identified (spectrum of consequences). They include the actual costs of preventive and failure replacement, and societal costs on the three strategic challenges of the company (Operation, Environment and Safety of third parties).

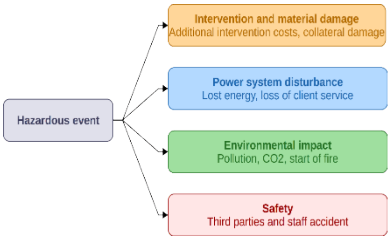

Figure 6: Identification of the consequences and strategic challenges of the company.

7. Optimal replacement policy

The optimal replacement age of an equipment depends on its ageing law and the evaluation of the consequences of failure. Equipment that is renewed too often costs too much in terms of maintenance policy, and equipment that is not renewed often enough costs too much in terms of consequences.

A balance must be found between the probability of failure and the consequences. The function to be minimized can vary to better reflect the intended maintenance policy.

The expected equivalent annual cost function is an example of the cost function to be minimized for an infinite decision horizon time:

$$C(a) = \frac{c_f\, F(a) + c_p\, S(a)}{MTBR(a)} \qquad \text{(4) cost function}$$

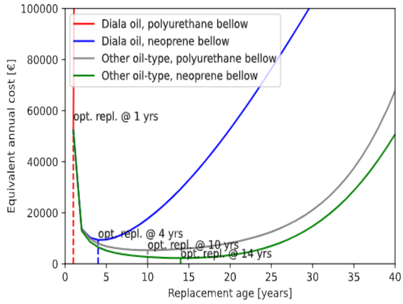

Figure 7: Equivalent annual cost for combined transformers EJ33 with 10M€ for the consequences.

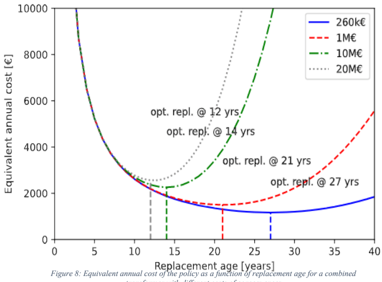

Figure 8: Equivalent annual cost of the policy as a function of replacement age for a combined transformer with different costs of consequences.

Conclusions

To define a risk-informed age replacement policy for ITs, Rte has followed the following steps:

- First, a survival analysis was performed to model the time to occurrence of the hazardous event.
- Covariates were taken into account to refine the survival functions and identify pathological equipment.
- Then, the consequences of failures, in terms of real and societal cost, and the cost of preventive maintenance was evaluated.
- A balance must be found between the probability of failure and the consequences. The function to be minimized can vary to better reflect the intended maintenance policy.