QUALITY POLICY BASED ON THE 'CRUCIALITY' OF THE ELECTRICAL DISTRIBUTION EQUIPMENT

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SUMMARY

Elaborating a quality improvement policy for electrical distribution equipment involves important policy options to be made. A recurrent question is "which quality improvement measures are economically justified and which are not ?"
This paper explains the 'cruciality' method as an approach enabling quantification of the 'cruciality' of each network component regarding quality improvement.
Significant savings are achievable and unjustified expenses are avoidable by firstly paying attention to the most critical or crucial component and by evaluating each measure separately.

INTRODUCTION

Nowadays and as far as costs are concerned, there is a trend to discard or to limit drastically quality measures on electrical distribution equipment like comparative tests, technical specifications, identification files, quality controls, maintenance and fault analysis. Limitation of abovementioned cost factors generates immediate savings, but can on longer term have extremely negative effects. It might indeed result in a negative cost-expenses balance owing to incidents and high costs due to fault occurrence.
On the opposite a quality improvement policy aiming at maximum reliability of the distribution equipment is not obvious considering the current economical context. Taken into account both these extremes there is, also for quality improvement a golden mean. In the present paper we will attempt to answer the recurrent question "which quality control measures are economically justified and which are not ?",
The first part gives a survey of the measures to be taken into account as to reduce the number, as well as the impact of incidents. Part two explains a method that enables quantification of the '<u>cruciality</u>' of each component in the distribution network. Finally a calculation method that should enable to evaluate each quality measure will be described.

QUALITY IMPROVEMENT POLICY FOR ELECTRICAL DISTRIBUTION EQUIPMENT

While working out the quality improvement policy, we will examine the possible measures as to reduce the number of incidents. This will be illustrated by the diagram in appendix 1. The column 'Steps' of the diagram shows different <u>steps</u> a component undergoes during its <u>lifetime</u>.
The first step is the <u>initial choice</u>. Regarding supply, potential suppliers and models have to be taken into account. The next successive steps are the <u>order</u>, the <u>supply</u>, the <u>installation</u>, the <u>commissioning</u>. After commissioning, the component is ready to achieve its function within the distribution network : the <u>utilisation</u>.
Some specimens will fail and generate <u>incidents</u> that will necessitate interventions. Incidents in the distribution network involve <u>fault costs</u>. Fault costs include intervention costs as well as costs resulting from the supply outage at the customer's. In well defined cases there are additional costs, such as hidden costs due to the lifetime loss of other components in the distribution network as a result of short-circuit currents or costs resulting from accidents with own personnel or thirds as victims.
Preventive measures can raise the equipment's reliability but involve also costs. The permanent aim is to reduce the <u>sum of the costs of the quality improvement policy and the fault costs to a minimum</u>.
Regarding quality improvement measures can be taken into account in different steps.

- The <u>initial choice</u> can be made after the thorough analysis of the component and its compliance with the standards. Referring to <u>comparative tests</u> the advantages and disadvantages of different technologies can be compared. When evaluating quality, there are two important elements : the intrinsic quality when mounted perfectly and the quality reduction as a function of the mounting tolerances. At last this can result in a <u>technical specification</u> that fixes the requirements each supply should meet.
- When a given product is certified or when it did meet the technical specifications at the initial choice, this does not mean necessarily that the quality will always be satisfactory at later supplies. A possible protective measure might be certification of the supplier's manufacturing chain, the approval of it and finally trust in the ISO 9000 certificate obtained by the production department. However, a <u>periodical quality control</u> is necessary as to limit possible faults to a minimum.
- Normally the supplier is obliged to inform the customer of any adaptation, as slight as it may be. The <u>identification file</u> is a reference tool that allows to verify adaptations or modifications to the product. Verifying compliance with the identification file may be

some part of the abovementioned periodical quality control.

- Installing the component requires an adequate procedure or working method. Training and motivation of the assembler are also very important.
- Commissioning can be combined with 'on-site' tests.
- It is obvious that judicious maintenance combined with diagnostics techniques and experience are extremely important as to prevent incidents. There is indeed an increasing attention for this aspect.

Perfecting and optimising of the abovementioned measures requires a sound product knowledge. In some cases comparative tests and thorough investigation of the component are not sufficient. For crucial components it is necessary to have a clear view of the number and type of incidents occurring on the network. Feedback from statistics and analysis of incidents should contribute to continuously adjusting the abovementioned steps in the different phases of the component's lifecycle.

THE CRUCIALITY - METHOD

When elaborating a quality improvement policy we should keep in mind that each component has not the same significance or cruciality and does not require the same attention. The consequences of an incident can vary significantly, depending on the concerned component.
For incidents also the 20/80 rule of Pareto is approximately valid: 80 % of the fault costs are caused by 20 % of the components, the so-called 'crucial' components. Efforts made to improve quality of the crucial components will generate the highest savings.
Elaboration of the quality improvement policy is a priority for crucial components.

Cruciality - investigation

As to determine whether the quality improvement policy of a component (or one specific measure of the policy) is economically justified or not, a cruciality investigation is always achievable. It enables to verify the cruciality level of a component's population concerned by the measure.

Definition of cruciality

The expression below allows quantification of the cruciality of a component's population.

The 'cruciality' of a component shows the achievable savings when the failure ratio of the component increases by 1/1000.

$$C = \frac{N \cdot G}{1000}$$

N = Population of the component influenced by the quality measure (number of specimens)
G = Average consequences of an incident (financial impact)

A detailed discussion of the factor G (=consequences) is included further in the paper.

Strategic significance

Significance of the same component type can vary, depending on its localisation in the network. Problems with the same circuit-breaker for instance can vary depending on its localisation in the network. An incident with a circuit-breaker in a strategic network will have more severe consequences than a similar problem with a circuit-breaker mounted further in the network. When the 'strategic significance' is high, it is always possible to perform a separate cruciality investigation on the population group with a high strategic significance the component belongs to.

Remarks

1. The cruciality of a component does not take into account the effective number of failures of the component. A small number of incidents on a given component does not mean that the component is not 'crucial'. As soon as an incident has far-reaching consequences and the component is frequently used, the component will become crucial and an elaborate quality improvement policy becomes necessary.
2. The concept "cruciality" relies on the assumption failures always occur. The precise effective failure ratio of a component does not influence its cruciality and therefore should not be known.
3. The cruciality definition takes into account the financial impact of an incident, at the moment of the incident. The considered costs are not actualised.

The consequences G

As shown in the previous section, cruciality is proportional with the financial consequences of an incident affecting the component. The financial consequences G of an incident can vary according to the incident type and the circumstances. When calculating cruciality, it is assumed that the incident is severe, which means that the incident results in destruction of the component's function (for instance a disruption in a low voltage joint). After investigation of some approaches the average cost of a severe incident is calculated (= factor G in the cruciality expression).

Classification of distribution equipment

The cruciality approach requires a classification of distribution equipment according to its functionality. As it is assumed that the function of the component is completely disturbed, the consequences will firstly depend on the component's function. A distinction can be made between 3 groups:

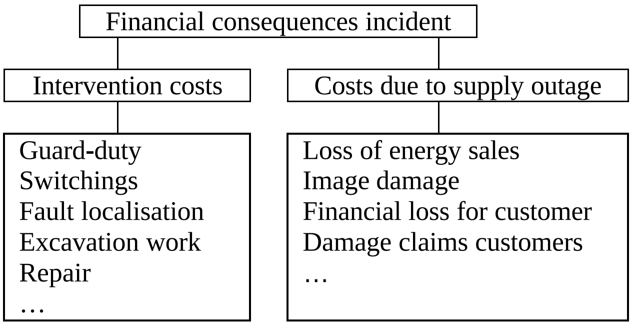
1. Network components: their function is supply of electrical energy to the branched customers.
2. Protection equipment : under normal operating conditions of the network these components have a passive function. They are only active in fault situations.

3. Measurement equipment

It should be noticed that the cruciality method is also implementable on the tools and the individual and collective protection means used by the time of installation, repair or maintenance of components in the distribution network.

Consequences G for Network components

The diagram below gives, as an example, a survey of the consequences of an incident on a group 1 component.



A severe incident on a network component will always result in an intervention. The most significant costs are imputable to intervention of the guard-duty, switchings, fault localisation, excavation work, repair and material costs. The sum of these partial costs represents the total intervention costs.

On the other hand, a severe fault generates a supply outage. As supply reliability is a very important quality parameter for the customer, each outage always represents important damage. Direct and indirect costs of a supply outage can be calculated.

<u>As to calculate the consequences G of an incident on a network component intervention costs and outage costs are summed.</u>

$$G = I + O$$

G = financial impact incident
I = intervention costs
O = financial impact supply outage, which is the cost price of the energy not supplied multiplied with a factor (f.i. 10) as to take into account damage claims, loss of image,…

DEVELOPED EXAMPLE: NEW LOW VOLTAGE BRANCH JOINTS

Low voltage branch joints are used for underground cable branchings to low voltage consumers. Maintenance being impossible, we are only interested in new specimens to be bought and installed. Consequently cruciality will deal with the amounts bought each year.

It is assumed that the yearly consumption of an electrical power supplier represents 100.000 low voltage branch joints.

What are the financial consequences under the assumption that 1 out of 1000 specimens fails ?

The consequences G of 1 incident are calculated by summing the average intervention costs and the direct and indirect costs of the supply outage.

A simple method as to calculate the costs of the supply outage involves an evaluation of <u>the total power</u> interrupted by the incident and <u>the average duration</u> of the supply outage. The energy that is not supplied (output x duration) is subjected to a penalty of 1,25 euro/kWh.

An incident on a low voltage branch joint will result in a supply outage on the LV cable. An output of 100 kW is interrupted for a period of 3 hours. The financial impact of the outage is:

O = 100 kW x 3 h x 1,25 euro/kWh = 375 euro

Additionally the intervention costs represent :

I = 2730 euro

Which enables calculation of G:

G = 2730 euro + 375 euro = 3105 euro

Consequently the cruciality of the component is worth :

$$C = \frac{100\,000 \cdot 3105}{1000} = 310500 \text{ euro}$$

FISH-BONE DIAGRAM (SEE APPENDIX 2)

The elaboration of targeted measures as to reduce the number of incidents necessitates a clear view of the failure causes and failure mechanisms. The results of a fault analysis can be displayed on a <u>fish-bone diagram</u>.

Generally 6 primary influence factors can cause failure of a component:

1. Men
2. Management
3. Medium
4. Material
5. Method
6. Machine

Each failure cause can be classified under one of the abovementioned factors. The example given in appendix 2 shows the cause-consequence diagram for incidents on low voltage branch joints.

ECONOMICAL JUSTIFICATION OF PREVENTIVE MEASURES

Each measure intended to improve quality of a component must be economically justified. The fault costs that can be avoided using these measures must be a multiple of the costs generated by these measures.

As to evaluate whether a measure is economically justified, a new concept is introduced:

ΔF_R = the failure ratio decrease required for justification of a given measure

$$\Delta F_R = C^{te} \cdot \frac{P}{C} \quad {}^0\!/_{00}$$

C^t = required ratio between the cost of the preventive measure and the avoided intervention costs

P = cost of preventive measure

C = 'cruciality' component

Example: low voltage branch joints

- A preventive measure (for instance periodical control tests on new equipment) generates an additional cost of 10 000 Euro/year.
- The cruciality of the component amounts to 310 500 Euro.
- The aim is to recover at least 5 x the costs of the quality measure (Constant = 5).

$\Delta F_R = 0,16\ {}^0\!/_{00}$

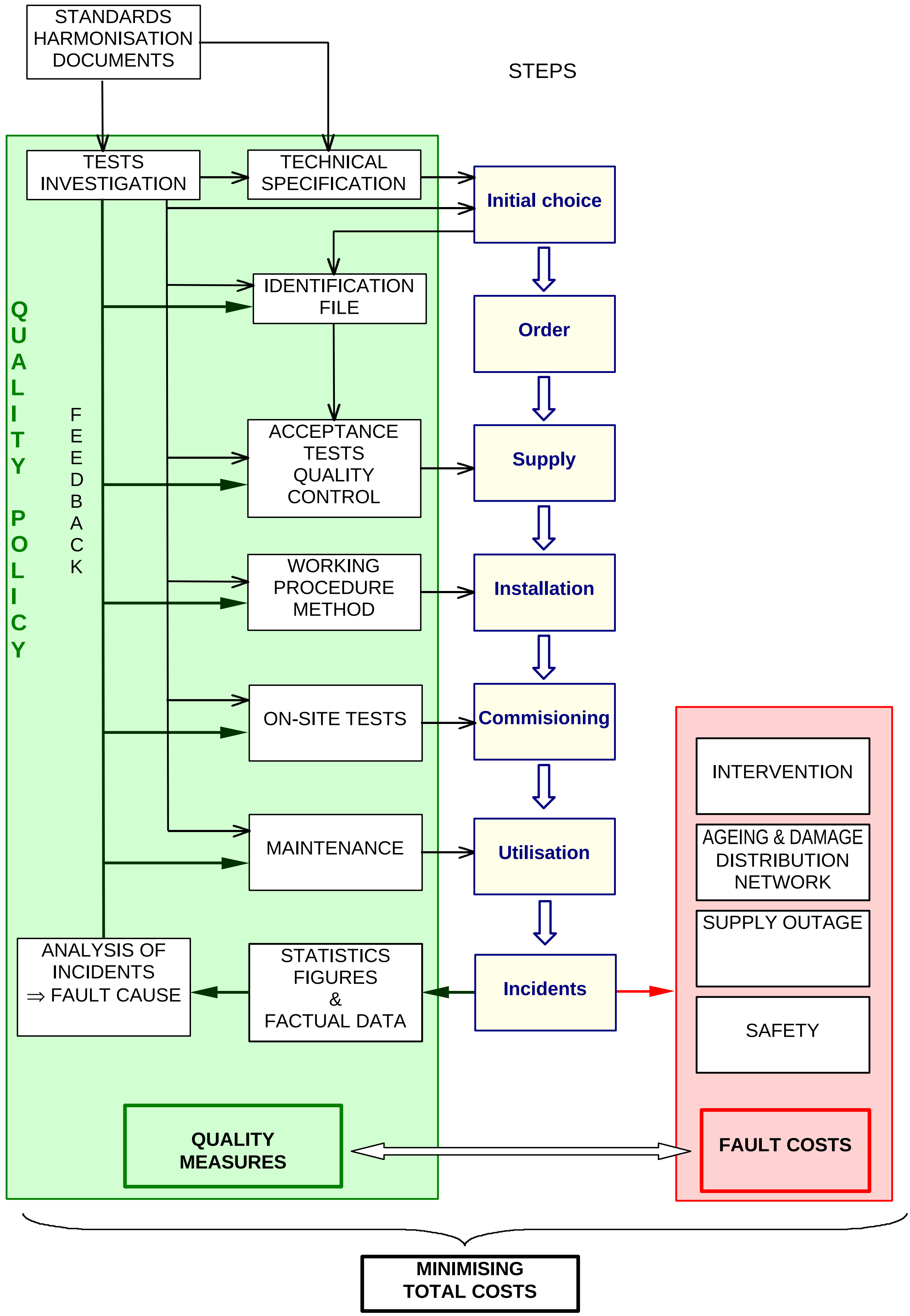
When the savings aimed at should amount to 5 x the expenses for the quality measures, the measure can be implemented when it is expected to result in a 0,16 ${}^0\!/_{00}$ decrease of the failure ratio or to prevent a 0,16 ${}^0\!/_{00}$ increase of the failure ratio.

CONCLUSION

Using the cruciality method, the quality improvement policy can be focused on the crucial components and the economical feasibility of each measure of the policy can be verified. The developed methodology has been applied to some practical cases. This resulted in measures liable to improve quality and also technically and economically feasible.

The classification of components according to their cruciality differs in numerous cases from the classification that might be given by intuition. Referring to the developed methodology intuitive considerations can be avoided. Instead, an objective and systematic approach can be adopted for the elaboration of quality improving measures.

APPENDIX 1



STANDARDS HARMONISATION DOCUMENTS
STEPS
TESTS INVESTIGATION
TECHNICAL SPECIFICATION
Initial choice
IDENTIFICATION FILE
Order
QUALITY POLICY
FEEDBACK
ACCEPTANCE TESTS QUALITY CONTROL
Supply
WORKING PROCEDURE METHOD
Installation
ON-SITE TESTS
Commisioning
INTERVENTION
MAINTENANCE
Utilisation
AGEING & DAMAGE DISTRIBUTION NETWORK
SUPPLY OUTAGE
ANALYSIS OF INCIDENTS ⇒ FAULT CAUSE
STATISTICS FIGURES & FACTUAL DATA
Incidents
SAFETY
QUALITY MEASURES
FAULT COSTS
MINIMISING TOTAL COSTS

APPENDIX 2:

Fish-bone diagram for low voltage branch joints.