EVALUATION OF THE MOUNTABILITY OF THE MEDIUM VOLTAGE ACCESSORIES

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ABSTRACT

One of the main objective of Enedis is to improve the reliability of the network. Considering that Enedis has over 300 000 km of medium voltage underground links, those links are crucial for the global reliability. The complete links are made of underground cables and accessories such as joints, connectors etc., and those accessories are known to be one of the weak points of the links. If we improve the reliability of the accessories, we will improve the reliability of the complete link.

To achieve this goal, we launched many investigations, studies and specific tests on the accessories. But we also know that one of the main reasons of the accessories failures is the human fitting error. That is why we decided to work on the topic of the "mountability" of the accessories.

The main goal is easy to understand, an accessory easy to install is an accessory installed with less errors, so it is a more reliable one on the grid at the end.

The topic of this paper is to know "How to evaluate this mountability". We will focus on medium voltage accessories because there are more critical in terms of grid reliability.

INTRODUCTION

In the distribution network, **the main causes of medium voltage underground links failure** are **failures during accessories installation**. The first way to improve the reliability of this installation is to provide an appropriate training to all jointers.

In France **all jointers have an initial training** including theory and practical exercises. After this training each jointer passes through an exam. This exam consists on preparing several accessories like joints, connectors etc. Every two years all the jointers pass through another exam in order to validate that they still have all the knowledge and the technical skills. This exam will allow them to install medium voltage accessories.

In the training course the jointer is prepared to work with several accessories but it is not possible to study all the accessories of all Enedis suppliers. So we consider that the training course give to the jointer all the technical skills that prepare them for working with all accessories.

Secondly **all the accessories pass through a complete qualification process**. In this process we verify the compliance with international and national standards. But we also have a mountability test. In this test we certify that it is possible to make this accessory, taking into account Enedis jointers rules.

And for each modification of the accessories we revaluate the instruction manual in order to keep an acceptable level of mountability.

Despite this process with both technical evaluation of the joint and training of the jointer, we still have many badly installed joints on the field. We need to focus on how we can improve this situation.

We **introduce the mountability as a purchase criteria** in order to reward easy to install accessories and to promote more reliable accessories on field.

In the following of this paper we will introduce how we evaluate this mountability of medium voltage accessories.

WHY DO WE NEED TO EVALUATE THE MOUNTABILITY?

The first question that we need to answer is: Why do jointers installations can lead to a service failure?

We tried here to list some of the possible reasons of those failures:

- Product training of the jointer,
- Time available to complete the installation,
- Workplace conditions (rain, temperature, dig size),
- Complexity of the operations.

We will analyse these reasons to know if they could significantly lead to failures.
Concerning the first reason we explain that all the jointers are trained to install properly medium voltage accessories. One of the limit is that the jointer cannot be trained on all the possible accessories that he may install. So we cannot ensure that the jointer is specifically trained on the products that we will install. But we have solutions to avoid this problem. We first need to ensure a **good quality of the initial training** in order to have adaptable jointers.

Then **the instruction manual** inside the accessories packaging **must be exhaustive and clear,** so that the jointer have all the information to install the accessory. We also need to ensure that there is coherence **between instruction manuals** of all of our suppliers and the jointers training.

Concerning the time available to complete the installation, we can **warranty** with **internal rules** an adequate work time to install accessories for each type.

For the workplace conditions it is **difficult to have uniform conditions,** because of a lot of environmental changing conditions. But we can put some rules in place in order to protect the workplace from the rain, to ensure a large workplace etc. This can minimize this effect.

Finally as far as the complexity of the operations is concerned, we already explained that we **validate only accessories** that we consider **easy enough** to be installed.

If we want to minimize failure during installations we need to minimize the effects of those reasons. The jointer does not install improperly an accessory on purpose, he does it because he has not the **proper information** or the **proper skill** at the **right time**.
Even if the information is present in the instruction manual, the jointer can do something else, because there is a fundamental difference between the instruction and the mental representation of this instruction for the operator. This difference could be explained for two main reasons: the jointer can have **internal rules** which conflict with the manual or more frequently the jointer can misunderstand an instruction because of a **cognitive overload**. The cognitive overload is a situation where a person has too much information or must perform too many tasks in the same time.

Indeed, the jointer, for each installation step, **must acquire enough information** in order to make this operation properly. Bu we need to take into account the fact that the working memory is limited. It is usually known in ergonomic studies that the working memory is limited to **three new data** at the same time. It means that if we write for a specific step in the manual an operation which is not standard or only founded in one accessory we need to ensure that this step is explained with no more than 3 new or specific information. Otherwise the jointer could be in a situation of cognitive overload and he will “miss” or minimize one of the new information.

Furthermore it is also known that the **eidetic memory** (or photographic memory) is **more efficient than textual memory**. It is easier for the operator to complete a task explained with schematics.

MOUNTABILITY EVALUATION

How to evaluate the mountability of an accessory?
We can consider that there are some objectives and measurable criteria. Those criteria could be: the number of pieces inside the packaging, the number of steps to make properly the accessory or maybe the average preparation time. It is obvious that **those criteria are non-pertinent** and mainly non-sufficient to compare accessories between them. Because there is a lot of important subjective criteria that we must take into consideration.

The criteria that we consider pertinent and subjective are the following:

- The clarity of the instruction manual
- The easiness of execution of the crucial steps
- The ergonomic of the storage inside the packaging
- The feedback of a successful installation step

In order to **evaluate those criteria** we rely on the **ISO 16982** [1] standard, **to avoid the possible subjectivity** of the study. This norm introduces the notion of **usability**. The usability is defined as the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use.
In our case, the goal of the jointer is to rebuild an underground cable with a joint (or another accessory). The usability of the joint is here similar to its mountability. In fact the cable is properly rebuilt if the joint is properly installed (considering that the technical performances of the joint are similar to the cable performances).
The usability methods are methods supporting human-centred design used for the purpose of increasing the usability of a product or a system. **Those methods can also be used in order to evaluate** those products or systems according to usability goals. In the following of this paper we will present those methods and present how we used them to evaluate the medium voltage accessories.

Those methods can be divided in two main categories. The methods involving the **direct participation of final users** and those involving **indirectly final users** (see Table 1).
Basic knowledge about the usability methods, including an understanding of their key differences and the basic principles of their application, is needed to be able to make an appropriate choice of usability methods.

Name of the method	Direct involvement of users	Short description of methods
Observation of users	Y	Collection in a precise and systematic way of information about the behaviour and the performance of users, in the context of specific tasks during user activity.
Performance-related measurements	Y	Collection of quantifiable performance measurements in order to understand the impacts of usability issues
Critical incidents analysis	Y	Systematic collection of specific events (positive or negative).
Questionnaires	Y	Indirect evaluation methods which gather users' opinions about the user interface in predefined questionnaires.
Interviews	Y	Similar to questionnaires with greater flexibility and involving face-to-face interaction with the interviewee
Thinking aloud	Y	Involves having users continuously verbalize their ideas, beliefs, expectations, doubts, discoveries, etc. during their use of the system under test.
Collaborative design and evaluation	Y	Methods which allow different types of participants (users, product developers and human-factors specialists, etc) to collaborate in the evaluation or design of systems.
Creativity methods	Y/N	Methods which involve the elicitation of new products and systems features, usually extracted from group interactions. In the context of human-centred approaches, members of such groups are often users.
Document-based methods	N	Examination of existing documents by the usability specialist to form a professional judgement of the system
Model-based approaches	N	Use of models which are abstract representations of the evaluated product to allow the prediction of the users' performance.
Expert evaluation	N	Evaluation based upon the knowledge, expertise and practical experience in ergonomics of the usability specialist.
Automated evaluation	N	Algorithms focused on usability criteria or using ergonomic knowledge-based systems which diagnose the deficiencies of product compared to predefined rules.

Table 1 : ISO 16982-Brief description of the Usability methods

There are many possible methods described in this standard and we use those ones:

- **Observation of users**: some experts observed jointers working.
- **Questionnaires**: we built up a precise questionnaire.
- **Interviews**: after the mounting of accessories some jointers were interviewed by experts.
- **Document-based methods**: we analysed the instructions manual of many accessories.
- **Expert evaluation**: an expert committee evaluated the mountability.

Expert evaluation and document based methods

Historically the first way that we choose to evaluate accessories was methods which does not involve directly the final users (in our case the jointers). The reason is obvious: it is easier and cheaper for Enedis to organize an evaluation with few experts than to bring many jointers together. This evaluation was done in 2012 and we used expert evaluation and document based methods. Some objective criterions based on quantifiable data have also been taken into account.

This study was first done for **medium voltage cold-shrinkable joints and derivations**. The cable experts were from the training and technical department and field accessories experts.

The document based method used the instruction manual provided by the supplier. This manual was evaluated by the experts step by step. They also consider some data included inside of the manual or the packaging (like the number of pieces or the number of figures in the manual). The experts also analysed the mountability by looking together a jointer working to make the accessory. They gave some notation for each step and those steps were weighted according to their criticality.
This study and the results of the evaluation were interesting **but this methodology has some limitation**. In fact it is very important to involve the jointers in the evaluation because they will install the accessories every day on the field. So they have the knowledge of what is important in terms of mountability.

Evaluation involving jointers

Following the experts evaluation of 2012, we decided to improve our evaluation methodology by involving jointers.
In this evaluation we integrated subjective items such as clarity of the instruction manual, easiness of execution or ergonomics of the packaging.
We used the **observation of users, the questionnaires, and the interviews** methods described in the ISO 16982.

The first step was to select **jointers with different profiles** in terms of age, expertise, and training. A good selection of the jointers is very important in order to **avoid selection bias** during the analyses of the results. In order to perform this selection we used the competences of our training department and their information concerning jointers. At the end, we selected 8 jointers from Enedis (it was unfortunately impossible to include external jointers for logistics reasons) very different in terms of age and skills. The youngest was trained 6 months before the evaluation and the most experienced had 20 years of experience in medium voltage accessories.

We chose to evaluate the **medium voltage cold-shrinkable joint** because it is the most used accessory in the French grid but the methodology can be used for all others accessories.

The idea of this evaluation was to have several qualified jointers and to give them some joints to make. During the operation some independent cable and accessories **experts observed** the jointer. Consequently a **30 minutes interview** between the expert and the jointer concluded this evaluation.

We chose experts from the training department and some researchers from EDF R&D department.
This evaluation was organized as following: each joint was evaluated during half a day. For each evaluation the **jointer read the instruction manual alone** and made the joint without help of the expert or from another jointer. During the installation, the jointer completed a questionnaire for each step of his work. We deliberately chose not to time precisely the installation because we really wanted to focus on installation difficulty and the quality of the instruction manual.
During the observation the expert evaluated with an outside view the **estimated difficulty experienced by the jointer**. At the end of the installation an interview between the jointer and the expert concluded the evaluation. The goal of this interview was to exchange the points of view between the jointer and the expert for each step of the installation. The conclusion was a global evaluation by the jointer.

Questionnaire development

The questionnaire was developed by taking into account the experience of training department, the field experience and the experience of the R&D department. We organized this questionnaire with different sequences. **Each sequence of the questionnaire** corresponded to an **installation step** common to most accessories.

For each sequence, the questionnaire was developed in the same way. The first question concerns the **clarity of the instruction** for this step. The second question concerns the **easiness to achieve this step**. And the last question concerns **the certainty of the step's achievement**. The last question is similar to: "Are you absolutely sure to have successfully achieve this step?"
And for each question the jointer needed to rate the assertion on a scale of 0 to 5 from 1= "I disagree" to 5= "I totally agree ".

Installation and Positioning of the cold-shrinkable body					
	I disagree	I rather disagree	I rather agree	I agree	I totally agree
The instruction is clear	☐	☐	☐	☐	☐
The body is easy to install	☐	☐	☐	☐	☐
I am sure that the body is correctly installed	☐	☐	☐	☐	☐
Comment					

Table 2 : Extract from the questionnaire concerning the installation of the joint's body

CONCLUSION AND RESULTS ANALYSIS

The global conclusion of this study is that the **instruction manual is the central support** to install correctly the accessories. Those instructions are unequal in terms of quality and one of the most important work for the future is to improve them. We also need to focus on the **schematics which are the more efficient way to provide a complex information** and we will work to develop a method to validate them. We also need to specify the **terminology** used in those manuals because today each supplier uses his own words to describe a technical action. It will be much more efficient to **harmonize this terminology** between the Enedis training department and supplier's instructions manuals.
The other global conclusion is that the accessories must improve their **affordance** (the affordance of a product is the ability of this product to suggest implicitly the way it must be used).

Furthermore, the result of this study is a **mountability benchmark of cold-shrinkable joints useful for Enedis**. Indeed, this benchmark will be used to purchase the best accessories and it **will certainly initiate an improvement of the mountability of all our accessories.**

REFERENCES

[1] ISO/TR 16982, first edition 2002-06, Ergonomics of human-system interaction — Usability methods supporting human-centred design