EVOLUTION OF THE FRENCH LV UNDERGROUND SERVICE CABLE

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ABSTRACT

For cost reduction purpose, EDF Distribution Networks decided to change the design of its LV underground service cable. After a deep opportunity study and a complex technical validation, the project has resulted in the deployment on the French network of a new model of LV underground service cable also used by the English subsidiary EDF Energy.

The evolution of LV service cable design is mostly characterized by replacement of lead covered solid aluminium neutral conductor (associated with a metallic screen for third-part protection) by a concentric copper wire neutral conductor.

This paper presents the technical and economical advantages of the new design and the technical issues highlighted by the project. It was discovered that all existing LV equipment, designed to accommodate aluminium neutral conductors had to be checked for compatibility with the copper wire screen of the new design and any alterations needed to be carried out at no extra cost. The paper also highlights the need to carry-out a deep impact study (technical compatibility and economical evaluation) before any proposed change is implemented.

This project was an opportunity for EDF group to successfully trial a new qualification method, with the conformity certification validated by a third party.

April 2005: The new LV underground service cable was deployed on the French network for the first time.

SITUATION ON PROJECT LAUNCH

The general purpose of the project was to achieve a comprehensive reduction in the cost of constructing low voltage cable networks, by changing the construction of the cable itself.

The original feasibility study centred on both the network and the service cable

At the outset of the project (end 2001), it had initially been envisaged to replace the lead-covered French low voltage cable (which is a very specific design) by a more common copper concentric neutral design. The opportunity study at that time focused on the network cable. The study included an economic and comparative assessment of existing cable models, investigation tests on the technical feasibility of using a concentric neutral design (compatibility of underground accessories and connections, conformance to mandatory third party safety requirements), surveys of end users, and prospective search for manufacturers.

Interesting prospects of savings from the new service cable

On completion of the investigations performed up to beginning of 2003 by EDF R&D, the concentric neutral design did not appeared economically viable for network cable purposes, even with hard optimisation actions. Furthermore, considerable technical risk of incompatibility was identified for a number of network connection components (connections between terminal boxes/boards). Economically, the overall cost was deemed to be prohibitively high.

The study also demonstrated that the concentric neutral service cable used by the English subsidiary EDF Energy was economically attractive. The identified technical risks were low (concerning the connection of the copper strands of the neutral conductor). The design featured a metallic screen providing third party protection (mandatory in France and the UK), and was suitable for all replacement cable laying situations in France. In addition, EDF Energy gave very good feedback on this design.

It was then been decided to study the development of the service cable and the network cable separately and to develop a new specification as close as possible to the British standard, whilst retaining some of the requirements deemed essential.

This choice gave the opportunity to undertake the process jointly with EDF Energy. The idea of a joint qualification system based on a new common specification was adopted.

RUNNING A MUTUALISED QUALIFICATION PROGRAMME

The joint qualification system for the supply of low

voltage service cables used by EDF and EDF Energy was published in the Official Journal of the European Union on 03/01/2004 and was conducted jointly by the two entities.

11 European applicants submitted requests for consideration on time, and were therefore reviewed.

Details of the joint specification of the copper concentric neutral service cable

In France, the lead-protected neutral service cable hitherto used is described in French standard NF C 33-210. The British concentric neutral copper service cable is described in the British standard BS 7870-3.11. Both standards are descriptive, as are all the LV cable standards in Europe.

Note – At the European level, the voluminous harmonization document HD603, describing low voltage 0.6/1 kV distribution cables, gives an idea of the diversity of models of low voltage cable in use in Europe (more than 50).

The joint specification project therefore considered a new specification. Put simply, the design requirements are close to the British standard, whereas the test requirements are closer to the French standard. Test requirements have been nevertheless significantly optimised from the former standard, in particular dropping the direct buried long duration test. There are fewer tests and they are shorter (max. of 14 days).

Note – Given that the new specification remains highly descriptive, and covers only service cables, EDF opted for a pre-specification long duration trial of the design for validation purposes.

The specification covers all the models used by the two entities. The range of cross-sections is therefore extensive. A model with low smoke release was introduced for the specific needs of EDF Energy and other models fitted with telecommunication unit[1] cable to cater for the specific needs of EDF.

To keep the design standardised it was decided that the telecommunication cable should not be built in to the power cable. However, to simplify installation, the specification requires the telecommunication cable to be attached to the external surface of the service cable (which avoids the problem of having to install the cables separately). The manufacturers were encouraged to propose solutions which could be manufactured within the capabilities of their existing production plant.

To make it easy to read, the format of the European harmonization document (HD) was adopted. All the references to standards in the specifications will be European (EN or HD) or international (IEC).

The main feature of the redesigned service cable is to switch from a solid lead-covered aluminium neutral conductor to a **helically applied copper wire conductor**. This meant all existing connecting devices (which were optimised for the aluminium conductors) are checked to ensure that they can accommodate the new cable's neutral conductor. When the technical and economic assessment was performed prior to the launch of the qualification system, the technical risks surrounding connection compatibility were identified but considered sufficiently low not to cause any further delay in project launch. However, it was agreed that exhaustive checks would need to take place on all of the equipment during the validation phase.

One of the benefits of this design not containing a lead covered conductor and steel armours is that the cables overall diameter is significantly reduced, making it easier to handle and install.

Single core cables
(French cable and new cable

Three core cables
(French cable and new cable)

TECHNICAL VALIDATION

Technical validation started with each candidate manufacturer handing over a technical dossier containing Identification and Credibility data, and prototype samples. Technical validation was in four parts:

- Type conformance ;
- Check of compatibility with existing connection equipment ;

1 The telecommunication unit is a device to enable remote meter reading from the connection box placed at property limits. For this purpose, meter information is transmitted in encrypted form through dedicated conductors laid up within a cable, the system being known as the telecommunication unit.

– Network installation trials ;
– Analysis of the identification and credibility dossier.

Original experience: Europe-wide certification

The method adopted for checking the conformance against the draft specification took the form of a type conformance certification (validation by third party of type testing to enable end users to gain confidence in the information provided).

As far as EDF was concerned, this was a first, an experimental approach to Europe-wide certification, and moreover, in regard to a new product.

The diverse origins of the manufacturers bidding to become EDF suppliers also made for an interesting interaction with various certification organizations.

Note – candidate manufacturers were required to hand over a certificate of type conformance issued by a certification organization accredited under standard EN 45 011. The accreditation organization was required to meet the standards of EN 45 010 and to have signed the multilateral mutual recognition agreements.

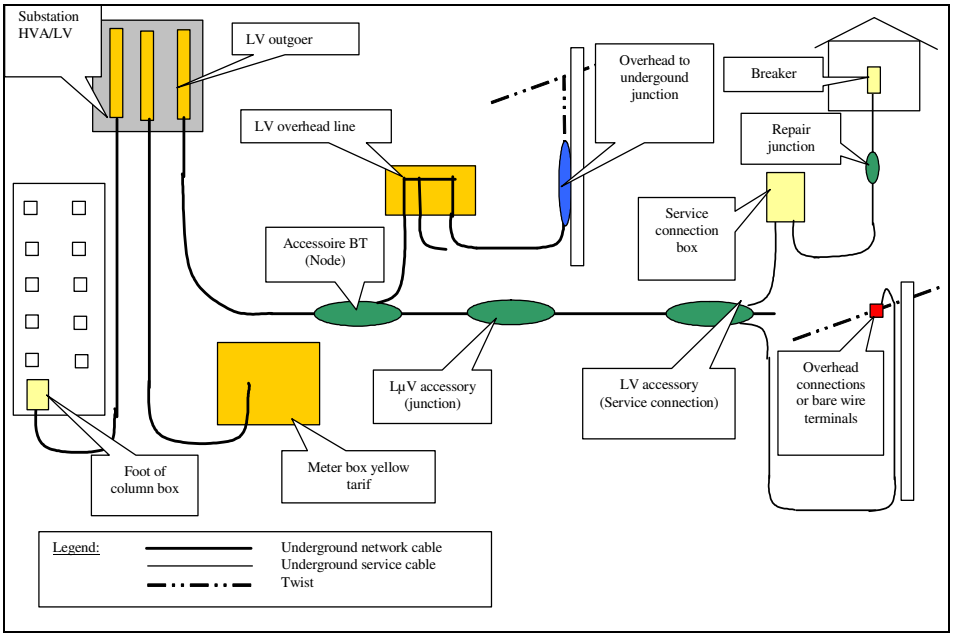
Of the 11 candidates, 8 candidates submitted valid type conformance certificates.

Verification of compatibility with existing connection equipment

The technical risks identified required exhaustive verification at the time of technical validation.

A characteristic of the low voltage networks is the multiplicity of small connection devices, and the large number of different actors (manufacturers, recommending organizations, purchasers, etc.**). This produces a large number of complex issues that need to be considered and mastered.** Compatibility checks were required for the following families of equipment:

- Underground cable joints
- Underground to overhead connections
- Outdoor connection equipment (connection boxes and outdoor branch connection equipment)
- Meter connection pieces



Main points of underground cable connection

Underground joints

The verification of the compatibility of the underground joint accessories raised no particular difficulties. This equipment was examined in-depth during the feasibility study. An additional functional requirement was resistance to moisture internal penetration, given that the requirement for cable longitudinal moisture ingress was cancelled. This development had been anticipated, and accessory specifications were changed, before the project got under way with accessory water penetration test being altered to utilise a lower water pressure of 0.5 bar.

The initial test requirement of 2.0 bar was not adapted to real condition of internal water ingress, given the usual difference of level between terminations and joints observed in France. The water pressure of 0,5 bar has been chosen as a technical and economical optimum after some investigation tests carried out at different level (0,1bar, 0,5 bar and 1 bar).

Outdoor connection equipment and meter connection pieces

For other families of equipment, the risk of incompatibility at time of project launch was deemed low. The required modifications appeared initially to be minor, as the majority of terminals in use were designed for copper conductors. Only the design of the neutral conductor (which had to be manually twisted to make the connection) was likely to affect the behaviour of the connections.

Nevertheless, it rapidly appeared that for the insulation piercing connectors widely used in France, the quality of the connection was especially sensitive to the shape of the copper stands manually put together.

Initial exchanges with some accessory manufacturers in February 2004 identified an emerging need to define a single method of preparing the neutral conductor. This would effectively demonstrate the compatibility of the products under identical conditions. The choice of a single method of preparation was a new constraint, but facilitated the laying up of the copper wires to form a conductor.

Given the large number of models and suppliers involved, the strategy adopted was to perform preliminary verifications in EDF R&D laboratories, and to set up a panel of suppliers representative of the different technical solutions encountered, before at the manufacturer's facilities. These preliminary verifications made it possible to pre-select the preparation method and minimize the list of tests and the range of equipment requiring for the new test. Validation procedures were therefore found to be more flexible and less costly.

The compatibility proved to be much more complex to ensure than expected. The immense difficulty of ensuring compatibility for all of the outdoor connection equipment gave rise to the need to make a number of developments in the preparation method (also making it necessary to repeat checks on other families of equipment). Many tests (mainly short circuit and ageing electrical test), which on a number of occasions were performed in EDF R&D laboratories, were required to achieve the definition of a specific material to re-insulate the neutral conductor (slip-on PVC or PE sheath with metal sleeve).

The proposed solution for re-insulating the neutral conductor was to involve "cold applied technology", so avoiding the use of the previously widely-used heat shrinkable sleeving, making it possible to lay up the neutral faster (avoid blow torch), and finally, reduce the reliance on complex detailed, high quality assembly work (no need for careful twisting).

The main characteristics of the neutral conductor re-insulation assembly were defined at the end of September 2004, to enable the award of the Temporary Authorisation for Use. The final specification had to wait until January 2005.

Three- phase and single phase cold shrink termination kits

Neutral slip-on sheath with metal sleeve

Overhead to underground join sleeves

Here, it appeared to be possible to use existing products. The validation phase led to the introduction of new products references for the new neutral conductor, which was in fact a mix of existing products.

Experimental work

Trials were part of the technical validation and a condition of the award of the Temporary Authorisation for Use. This related not only to the cables proposed by all candidates, but to the adjustment of the underground accessories and the terminations, to fit the new method of neutral preparation.

The purpose of which is to check that the cable could be set up without difficulty by regular users. An

initial review took place at the end of August 2004 to enable award of temporary authorisation of use. Trials were subsequently extended to approve the modifications of underground accessories. These adaptations also made it possible to upgrade the method of neutral conductor preparation and finalise the required tooling solutions.

Experimental work did not bring to light any particular difficulties of implementation for the installer (cable drawing or conductor preparation). Overall, the ease of handling of the single core cable was appreciated and the new cable as whole was well accepted.

Furthermore, the trials provided important feed back about the various solutions offered for the methods of attaching the telecommunication cable and power cable together, as proposed by the cable manufacturers. The various solutions were tested (twists or parallel assembly with oversheath, string or helical ribbon). Parallel assembly methods were preferred to the twisted solutions offered.

Tooling

The question of tooling was examined as soon as the opportunity study was launched. Preliminary workshop experimental work confirmed that the new cable could be prepared in a safe manner with existing tools, although some tools needed to be prohibited.

A solution to adapt a number of prohibited tools was proposed.

FINAL ASSESSMENT OF PROJECT

Positive technical and economic assessment

The new cable has been used on the French network since April 2005.

The project gave rise to **substantial overall savings**.

The old and new models of cable co-existed in the new contractual period. The strategy allocating them the same reference number ensured that the new cable was used as part of a flexible approach that did not exclude historical suppliers.

The verification of the compatibility of all connection components (particularly numerous on low voltage cable) took place in 6 months in spite of technical difficulties. But that has eliminated any potentially dangerous problems with connection devices. This experience has therefore confirmed the need to follow a serious technical validation phase even in the case of small changes.

Controlled deployment

The concentric neutral construction was accepted by the assemblers. There were no difficulties in preparing the neutral conductor. A single mode of preparation was proposed, and represented an improvement over existing working practices. It requires the use of specifically adapted cold applied terminations to ensure new cable and connection compatibility. This solution is not without economic impact (equipment purchases), but it avoids the use of previously widely used heat-shrinking sleeving. **Cable preparation is therefore faster, and it is easier to accomplish to the required level of quality**. The risk of bad connection is therefore reduced as well.

After some problems with cable quality on delivery and of availability of certain items of equipment were resolved in early months of introduction, the deployment of this new cable was successful.

REFERENCES

HD 603 S1 Distribution cables of rated voltage of 0,6/1 kV