SHORT LITERATURE SURVEY ON THE RELIABILITY OF EHV XLPE CABLES

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Date: January 14, 2005

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1 INTRODUCTION

In this short survey, literature from three major recent conferences on EHV power cables are studied in order to find the present opinion of utilities and other important companies (R&D groups, test houses, manufacturers) on the reliability of EHV XLPE cables. EHV stands for Extra High Voltage which roughly covers the voltage classes starting with 220 kV. These conferences are:

- the Cigré conference in Paris, August 2004: Chapter 2,
- the Jicable conference in Versailles, June 2003: Chapter 3
- the Cigré conference in Paris, August 2002: Chapter 4.

Cigré is a world-wide operating organization, covering all electric power aspects, mainly directed to HV and EHV. Every two years there is a conference with participants from all over the world, showing the latest developments on these items. Power cables has its own committee and paper session. The committee HV cables (B1) arranges studies by working groups on important subjects on power cables, some of their work is reflected in papers. Furthermore, the papers come from other sources. Information can be found on their website www.cigre.org.

Jicable is a conference organised by the French SEE (www.see.asso.fr) on power cables only, but now covering low, medium, high and extra high voltage cables. It is one of the largest conferences in the world on power cables only, held each 4 years, attended by many important utilities, manufacturers, etc. Their Jicable website comes alive when a new conference is approaching, expected in 2007.

Both conferences, from Cigré and Jicable, are not scientific, as sometimes IEEE related conferences are. Their approach is more practical and comparable to the ICC (Insulated conductor conference approach (www.ewh.ieee.org/soc/pes/icc), well known in the USA. Since EHV XLPE cables have their basis in Europe and Asia, it is also a fact that main developments and recent opinions are probably covered by Cigré and Jicable, being a reason to restrict the short survey to these conferences.

The main conclusion from the literature survey are drawn in Chapter 5 and references are specified in Chapter 6.

2 LITERATURE FROM CIGRE 2004

In reference [2] information is given about the reason why various countries in the Asian region are switching to XLPE, leaving fluid filled cables. In this reference, it is not only stated that there are very few problems with the performance of new XLPE cables, but that there is concern about the remaining life off older cable types. This is related to the water tree degradation, extensively
discussed in among others [3]. Nowadays this ageing problem is fully under control, due to reliable testing and additional water protection measures in XLPE cables. In the 10 Asian countries involved, XLPE cables are used in Indonesia up to 150 kV (chosen for reliability reasons!) to Japan up to 500 kV.

Reference [2]

To further CIGRE representation in the Asian region a workshop was conducted early in 2003 under the sponsorship of the Malaysia National Committee of CIGRE. There was representation from cable experts from 10 countries in the region. The purpose of this paper is to provide a report on the issues raised at that workshop with the objective of sharing the experiences of this region with the broader international community and at the same time, encouraging greater participation in CIGRE by experts in this region.

2. DESIGN PRACTICES – CABLE - ACCESSORIES – SYSTEMS

2.1 XLPE cable design. Most countries agreed that due to maintenance problems with fluid filled cables they were adopting XLPE. They agreed that overall there are very few problems relative to the performance of new XLPE cables but some very significant concerns by a number of countries in regards to the remaining life and performance of early XLPE cables, particularly those which did not have fully sealed metallic sheaths. On the other hand, Japan suggested the trend might be to make EHV cable without a metallic sheath or to accept the Moisture Barrier designs. Japan also proposed the introduction of DC – XLPE cable up to and including 500 kV.

Reference [4] is from cable manufacturer Brugg, from Switzerland. This manufacturer claims that he delivered 20 km of XLPE cable in the voltage range of 300 to 400 kV, with 93 accessories, installed in the last ten years and having excellent service behaviour. This information was not verified by independent parties, but on the other hand, there have been no messages from customers so far disputing the manufacturer’s statement.

Ref [4]

<table>
<thead>
<tr>
<th>Rated Value</th>
<th>66 - 100 kV</th>
<th>110 - 170 kV</th>
<th>170 - 300 kV</th>
<th>300 - 500 kV</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>km</td>
<td>20</td>
<td>1,000</td>
<td>2,186</td>
<td>10</td>
<td>1,346</td>
</tr>
</tbody>
</table>

Table 1. Experience in HV- and EHV-XLPE-cables

<table>
<thead>
<tr>
<th>Rated Value</th>
<th>66 - 100 kV</th>
<th>110 - 170 kV</th>
<th>170 - 300 kV</th>
<th>300 - 500 kV</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Locs</td>
<td>95</td>
<td>531</td>
<td>1,066</td>
<td>95</td>
<td>6,800</td>
</tr>
</tbody>
</table>

Table 2. Experience in prefabricated and pre-tested accessories
Reference [5] is from some important Japanese Tokyo Electric Power, Cansai Electric Power and Chubu Electric Power, with support of Japanese cable manufacturers. In their introduction they state that “This (XLPE) cable is capable of handling currents of up to (a voltage level of) 500 kV, and has been successively used in practical applications. In fact, Japan is leading in the world concerning the application of EHV XLPE cables.

Ref [5]

1. Introduction

In Japan, the realization of high density power transmission in major city areas requires the effective utilization of limited underground space, available, for example, in tunnels and ducts. Thus, for many years, particular efforts have been directed towards reducing the construction period, cutting the cost, and improving the reliability of extra-high voltage lines. This has necessitated a reduction in the number of joints, and thus long cable manufactured in continuous length had to be transported from the factory to the installation site, an undertaking that required the development of technology to installation the cable directly from the unloading point. At the same time, it has become essential to maximize the transportation length of the cable and to reduce its weight. In response to these needs, cross-linked polyethylene insulated cable with a reduced insulation thickness and the joints suited to it has been developed in Japan. This cable is capable of handling currents of up to 500 kV, and has been successively used in practical applications.

Pirelli also claims that EHV XLPE cables have excellent reliability, see reference [6]. As with Brugg cable, in the case of this manufacturer too some suspicion concerning the claimed XLPE cable behaviour is correct. But also in this case, concerning the cables discussed by Pirelli, no conflicting messages are known.
The first paper with interesting information is from ABB [7]. ABB takes the present experience with their cables and accessories operating at stress levels of 12 to 14 kV/mm as an expectation for other operating systems that could work on the actual EHV voltage class range at a similar electric field stress of 12 to 14 kV/mm due to other dimensioning of the cable. Although this extrapolation has some drawbacks, it is a reasonable approach. ABB assumes that based on this approach, for EHV cable this would lead to 0.024 failures per 100 km per year (or 0.038 failures per 100 miles per year), and for the EHV accessories about 0.01 failures per 100 accessories per year. In reference [1], an XLPE double circuit of 15.5 miles with 48 accessories per circuit phase (= 288 accessories in total) has been chosen for comparison with a HPFF cable. For such an XLPE cable double circuit, the ABB figures in this reference would lead to a total number of faults in 40 years of 1.4 failures for the cable and 1.2 failures for the accessories, making in total about 3 failures for this 15.5 miles double circuit per 40 years. This is an excellent reliability indeed (if ABB’s assumptions are correct).
The second relevant paper on EHV cables showing major projects realized in Europe is [8]. This paper describes the standards applicable to EHV cables, but also gives a good overview of documents created by Cigré working groups, which are supporting people that are dealing with these cables. Moreover, and that is important here, the authors say that the experience with EHV cables in Europe is very good. All the existing circuits are summarized. The paper has authors from European cable manufacturers only, but as far as KEMA is aware, all statements made by the authors are correct.

The 400 kV XLPE cable projects mentioned in this paper and completed at least one year ago:

- Germany, Berlin (1998-2000), 70 km single core cable in a tunnel, 1600 mm² Cu, 78 prefabricated and premoulded joints
- Denmark, Copenhagen (1997-1999), 104 km single core cable direct buried, 1600 mm² Cu, 114 prefabricated and premoulded joints

The 400 kV XLPE cable projects underway or just completed are

- Spain, Madrid (2004) 78 km single core cable in a tunnel, 2500 mm² Cu, 96 prefabricated and premoulded joints

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Ref [7]

<table>
<thead>
<tr>
<th>Population</th>
<th>Failure rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cables (1973-2003)</td>
<td>0,024</td>
</tr>
<tr>
<td>Tape molded joints (1982-2003)</td>
<td>0,013</td>
</tr>
<tr>
<td>Prefabricated terminations (1985-2003)</td>
<td>0,008</td>
</tr>
<tr>
<td>Prefabricated joints (1990-2003)</td>
<td>0</td>
</tr>
</tbody>
</table>

As can be seen, the failure rate of the insulation systems is very low (implying a very high reliability).
• Denmark, Jutland (2004) 84 km single core cable direct buried, 1200 mm² Al, 96 premoulded joints
• UK, London (2005) 60 km single core cable direct buried, 2500 mm² Cu, 60 pre-fabricated joints.

Ref. [8]
For example, the first 225 kV extruded cable was installed in Europe (France) in 1969 and is still in operation, with excellent service reports. Similarly, 400 kV extruded cables have been used in French nuclear plants since 1985. Later, the first large 400 kV extruded transmission underground systems were installed in Europe: Denmark, Germany then Spain. When designing, testing, manufacturing and installing EHV cable systems, European cable manufacturers followed IEC 62067 standard as well as all existing recommendations issued by CIGRE SC B1.

4 LITERATURE FROM CIGRE 2002

No relevant papers on reliability issues were found.

5 CONCLUSIONS

In general, this short survey gives the impression that utilities and manufacturers are satisfied with the reliability of EHV cables so far. Reliable data over a long period of application is not available, such cables are too short in service, with most projects realized in the last 10 years.

6 REFERENCES


