A survey of the flashover performance of HVDC converter station insulators

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Abstract: The operational experience of most of the HVDC converter stations in the world has been investigated, summarized and analyzed with regard to external flashovers across station insulators and apparatus. At some stations, some of the insulators have caused several flashovers soon after commissioning. The maximum flashover frequency occurred between 1987-1989, totalling about 20 flashovers per year at the 24 to 32 stations in operation. Several efficient countermeasures or maintenance methods have been developed. After the introduction of such measures, flashover frequency has normally been reduced to almost zero. During the last four years, the number of flashovers per converter station has been about 0.10, corresponding to about 0.05 per pole.

Keywords: HVDC system, External insulation, Station insulators, Maintenance, Countermeasures, Flashovers.

I. INTRODUCTION

Since the year 1954 ABB has supplied about fifty HVDC transmission converter stations for operation in various environments, from clean to severely polluted. Depending on the degree of contamination and on weather conditions, flashover problems of varying proportions have arisen. Countermeasures for preventing further flashovers were then taken. Operating experience from these stations provides valuable information for the design of future outdoor insulation and the performance of the external insulation has therefore been followed up continuously.

This paper presents and discusses the extent of the problem and the efficiency of the various countermeasures adopted at the stations in order to find satisfactory answers.

II. SCOPE OF THE PAPER

Of the 50 or so stations, supplied by ABB, operating around the world, 45 stations were included in this survey, all part of one of the following transmission systems: Baltic Cable, CU, Fenno-Skan, Geshouba-Shanghai, IPP, Itaipú, Konti-Skan 1, Konti-Skan 2, Nelson River, New Zealand, Pacific Intertie, Quebec-New England, Rihand-Delhi, Skagerrak 1+2, Skagerrak 3 and Vancouver Island.

The stations listed above account for about 660 station years, corresponding to about 1230 pole years. They represent about 80% of electric power transmitted in HVDC links (back-to-back stations not included).

To provide more precise information, the number of poles in operation will be used below instead of the number of stations, as the stations vary a great deal in size. The pole voltages range from 250 up to 600 kV DC. The study period extended from December 1982 to March 1998. Earlier studies by ABB on this subject were published in 1984 [1] and 1991 [2].

III. FLASHOVER STATISTICS

A. General

Typically, at some converter stations, certain insulator types suffer flashovers during the first period of operation. Such insulators have been wall bushings and apparatus porcelains with large diameters. However, countermeasures of various kinds were introduced at these stations and the problem has been overcome.

B. Flashovers and number of poles in operation

The number of poles in operation and the total flashover incidents that have occurred per year are shown in Fig. 1. Only external flashovers are included in these statistics.

![Graph](image-url)
At the beginning of the study period, about 10 flashovers occurred per year at the 26-50 poles in operation by that time. In 1989 the total number of flashovers reached its maximum, with 23 incidents reported at the 62 poles in service. During the last four years, the number of flashovers has been quite low.

At the beginning of the study period the number of flashovers per pole and year was about 0.3, and reached a maximum value of nearly 0.45 in 1987 - see Fig. 2. Since then, this number has been substantially reduced and in the last four years it has been kept as low as about 0.05.

In agreement with earlier statistics [1][2], horizontally mounted wall bushings have accounted for the majority of flashovers. The second most flashover-sensitive insulators have been apparatus porcelains with large diameters. Flashovers across post insulators are rare. Flashovers across bus post insulators have occurred only at one station and account for 8 of the total of 12 such incidents reported during the whole study period (Dec. 82 to March 98). Three flashovers occurred on post insulators positioned under some type of mechanical structure and for the 12th case detailed information is missing.

With regard to weather conditions, most of the flashovers occurred in rain, and rain intensity does not seem to have had any significant influence, see Fig. 4.

![Fig. 2. Number of flashovers per pole and year.](image)

### C. Mounting position, insulator type and wetting conditions.

Interesting questions are: what insulator types suffer most flashovers, and in what type of weather flashovers normally occur, see Figs. 3 and 4.

![Fig. 3. Percentage of flashovers as a function of mounting position and insulator type.](image)

<table>
<thead>
<tr>
<th>Mounting position/Insulator type</th>
<th>No. of flashovers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall bushings</td>
<td>1</td>
</tr>
<tr>
<td>Vertically mounted</td>
<td>39</td>
</tr>
<tr>
<td>Horiz. mounted</td>
<td>28</td>
</tr>
<tr>
<td>Vertically mounted</td>
<td>28</td>
</tr>
<tr>
<td>Other insulators</td>
<td></td>
</tr>
<tr>
<td>Post inul.</td>
<td></td>
</tr>
<tr>
<td>DCCT’s</td>
<td></td>
</tr>
<tr>
<td>React. &amp; transf.</td>
<td></td>
</tr>
<tr>
<td>Unknown insul. types</td>
<td></td>
</tr>
<tr>
<td>Vertically mounted</td>
<td></td>
</tr>
<tr>
<td>Wall bushings</td>
<td></td>
</tr>
</tbody>
</table>

![Fig. 4. Percentage of flashovers as a function of wetting conditions.](image)
Regarding the wall bushings, practically all flashovers occurred in rain. We see two reasons for this; one, the well known uneven wetting phenomenon [3] whereby more flashovers are provoked in rain conditions. The other is that the horizontal wall bushing normally maintains a lower pollution level due to better rain cleaning conditions, which gives better voltage withstand strength in fog.

D. Polarity influence

Another question is whether or not the polarity of the DC stress influences the risk of flashover. As can be seen in Fig. 5, wall bushings (horizontally mounted) mostly flash over at negative polarity whereas some vertical insulators have mostly flashed over at positive polarity. The fact that wall bushings flash over more at negative polarity has been discussed in literature [4].

Fig. 5. Number of flashovers as a function of insulator type and polarity.

IV. MAINTENANCE AND COUNTERMEASURES

Six different categories of maintenance and/or countermeasures for the most flashover-sensitive insulators have been identified among the stations examined in this study: no maintenance at all, cleaning, application of silicone rubber, application of silicone grease, booster sheds, and other solutions. The percentage of stations using the different methods is indicated in Fig. 6.

About 10% of the stations need no maintenance at all to keep their insulators free from flashovers. In about 30%, cleaning alone is sufficient and satisfactory. Insulator coatings are used in about 45% (normally only for a few flashover-sensitive insulators), booster sheds in 9%, and other solutions in about 5%.

Silicone grease coatings at the converter stations are currently reapplied after one to five years. The full lifetime of the coating, however, is seldom reached. In many cases, we have found it possible to extend the service life of a coating significantly by using better methods for monitoring of its condition. Other possible improvements that can be made without any deterioration in performance are the use of much thinner layers and better methods for application and removal.

The RTV coatings have so far not been reapplied at the stations where they are used, in one case lasting for more than 10 years. On the other hand, flashovers with such coatings have occurred after only a couple of years of use, and in some cases there are plans to change to silicone grease.

The efficiency of the different types of countermeasure has proved to be high, see Table 2. The performance of a coating will, of course, depend on the degree of monitoring and maintenance of the same.

TABLE 2. THE EFFICIENCY OF DIFFERENT COUNTERMEASURES AGAINST FLASHOVER.

<table>
<thead>
<tr>
<th>Countermeasure</th>
<th>Stations using the measure today</th>
<th>Stations where flashovers occurred in spite of the measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Booster sheds</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>RTV</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Silicone grease</td>
<td>14</td>
<td>1</td>
</tr>
</tbody>
</table>
V. CONCLUSIONS

The operational experience of most of the HVDC converter stations in the world has been investigated, summarized and analyzed with regard to external flashovers across station insulators and apparatus. At some stations, certain insulators caused several flashovers right at the beginning of their operation. The maximum flashover rate occurred between 1987 and 1989, involving about 20 flashovers per year with 24 - 32 stations in operation, corresponding to 50 - 62 poles. The most flashover-sensitive insulators have proved to be wall bushings, followed by large-diameter apparatus housings. The majority of wall bushing flashovers occurred in rain and at negative polarity.

Several countermeasures or maintenance methods exist. Since the introduction of such measures, the flashover rate has been reduced to almost zero. Over the last four years, the number of flashovers per converter station has been about 0.10 or about 0.05 per pole.

With regard to the possibility of reducing the maintenance of silicone grease coatings a considerable potential has been identified and experienced.

VI. REFERENCES


VII. BIOGRAPHIES

Bengt Almgren was born in Gävle, Sweden in 1939. He graduated at Gävle Technical College in 1961. In 1964 he joined the ASEA Central Laboratory in Västerås, working with development design and marketing of electro-hydraulic equipment. In 1972 he joined ASEA Brazil, first working with marketing of industrial equipment and latterly as manager of a design department for HVDC thyristor valves. In 1983 he joined the ASEA AB HVDC department in Ludvika where he then worked with following up HVDC converter stations, sizing of new ones, and research, all with regard to external insulation. In 1997 he was appointed as Company Specialist in the 'External insulation of HVDC transmissions' area.

Urban Aström was born in Njurunda, Sweden in 1946. He received his M.Sc. degree in physical engineering and B.Sc. degree in astronomy from the University of Uppsala, Sweden in 1973. In 1974 he joined ASEA AB's HVDC department and worked with design and development of control equipment, thyristor valves and valve cooling. In 1978 he joined the transformer department and worked with design of converter transformers for HVDC. In 1986 he joined the HQ/NEH HVDC project team, being responsible for converter equipment. From 1988 to 1995 he was manager of the HVDC Project Engineering Development department, and since 1995 he has managed the Converter Valve Development department.

Dong Wu was born in Beijing, China in 1952. He graduated from Xian Jiaotong University, received his M.Sc. degree from the Graduate School of EPRI of China, and gained his Ph.D. from the Royal Institute of Technology of Sweden, in 1977, 1982, and 1988 respectively, all in electrical engineering. From 1982 to 1985, and from 1988 to 1992, he worked as a Senior Research Engineer at EPRI of China. In 1992, he joined a research group as Project Leader in the Dept. of Electrical Plant Engineering at the Royal Institute of Technology in Sweden. In the period 1992 to 1997, he worked as a Project Manager at the High Voltage Research Laboratory in the Swedish Transmission Research Institute (STRI). Since January 1998, he has been with ABB Power Systems, working in the Converter Valve Development department. He has worked in the field of power electronics and high-voltage engineering. He is active in CIGRE and IEC task forces for outdoor insulation.