NAME : José Antonio d'Affonseca Santiago Cardoso
COUNTRY : BRAZIL
REGISTRATION NUMBER: DLG5196

GROUP REF.: D1
PREF. SUBJECT: PS1
QUESTION N°: 1.05

The main objective of this work is to discuss the tests necessary to support the live line work methodology. It is presented the test results for the minimum approach distance - MAD and the minimum number of insulators in good condition, considering the real transmission system arrangement and live line procedure, bringing confidence to the theoretical analyses.

In Brazil, the live line work has been performed in all extra high voltage classes, 500 kV and 750 kV AC and 600 kV DC for a long time. The procedures are supported by international standards (up to 800 kV AC only) and by the utility electricians' team experience. Considering this experience and the background in lower voltage classes, a methodology for the ultra-high voltage DC was evaluated in theory and in a practical manner. Laboratory work was done by an actual electricians' team in an 800 kV DC representative TL arrangement, to prove its feasibility. Cepel has done the research for the first Brazilian HDVC system in the 80ies, the ±600 kV Itaipu transmission system. At that time, similar tests were carried out in Cepel´s indoor HV laboratory to define the procedure of replacing damaged insulators by removing the entire string.

The practical evaluation is crucial, considering that not only the voltage level is important, but many other aspects related to the transmission system take part in the live line work. The following aspects were considered or represented in the tests conducted:

- Insulator string configuration (suspension "I" or "V"),
- The transmission tower configuration (insulation distance),
- The length of the insulator string (number of insulators),
- Insulator type,
- Transmission line configuration,
- The maximum system overvoltage,
- Linemen access mode to potential,
- Live line tools employed to the service,
- The climate and altitude conditions.

There are similar transmission systems in operation, in terms of voltage type and of construction, but the same procedure and safety distances could not be guaranteed between them. In the case of DC systems, the Itaipu system, like others in Brazil, uses glass cap and pin insulators in an "I" insulator string configuration. This project adopted 30 insulators with 170 mm spacing in between. The Madeira system (2013) ±600 kV uses 29 glass cap and pin insulators with 205 mm spacing. Yet, the two ±800 kV bipoles adopt 40 glass insulators with 205 mm spacing in between.

Outside Brazil, there are also UHVDC systems in operation, and they were considered for the procedure investigation. In the literature review, it was found that in China, live line work is executed in the 800 kV DC lines. In their case, as the suspension strings are in "V", the access method is through an insulating ladder, which is quite different from the one proposed in this article for the "I" string. Here it uses blocks and an insulating chair that allows reaching anywhere in the "I" string, while it is impractical with the insulating ladder.

Taking those into account, it is assumed that the results are not directly transferable for different voltages levels. Each situation must be individually evaluated for safety purposes. Therefore, laboratory test results are a valuable resource to support the live line work development. Complementing, the current IEC Live Working standard, with its analytical way to calculate the safety values, but not covering all the practical possibilities.

New challenges to implement live line work must be researched, including ultra-high voltage levels, optimized transmission system configurations, and the effect of AC and DC electric fields on electrician health. For example, the shielding requirements for the conductive clothing are higher for live line work in a UHVDC system, and consequently, the available clothing had the shielding performance evaluated in a laboratory.

Considering the importance and the challenges of establishing a test procedure to evaluate live line working, this topic should be discussed more deeply in Cigré.