Design criteria and simulation methodology for HVDC GIS/GIL

1. Context

Due to the development of High Voltage Direct Current (HVDC) technology which is particularly suitable for the transmission of large amount of energy over long distances and for off-shore energy integration, new technology for HVDC Gas Insulated Switchgears (GIS) and Gas Insulated Lines (GIL) is developing thanks to its compactness and its high reliability for application in HVDC switchyard.

Development and dimensioning of HVDC GIL and GIS requires deep knowledge on electric field distribution in the gas/solid insulating systems. The electrical field distribution changes progressively from a capacitive state which depends only on permittivity to a resistive state which depends on permittivities and conductivities of gaseous and solid insulations. Moreover, various factors like the temperature gradient due to the nominal current, the charge carrier generation in gas due to the gas moistures or the roughness/imperfections of high voltage electrodes, the interface charge accumulation at the interfaces between gas/solid, the space charge accumulation inside solid spacer can influence strongly the electric field distribution and thus the withstand voltage and the reliability of the HVDC system.

For a reliable design of HVDC GIL/GIS, the phenomena understanding, the material's characteristics, the simulation methodology/model must be mastered in order to take into account the specific nonlinear properties of insulating materials and the specific phenomena at the operating conditions: high DC voltage and with temperature gradient. Moreover, simulation for DC apparatus requires, unlike under AC voltage, consideration of many physical phenomena as described in table below.

	AC	DC
Capacitive field distribution	Y	Y
Resistive field distribution	N	Y
Transient calculation	N	Y
Temperature gradient	N	Y
Surface charge accumulation	N	Y
Charge emission	N	Y

Finally, as stresses and test requirements for DC apparatus are not the same as the one under AC voltage, specific design criteria must be defined.

2. Products proposal

SuperGrid Institute proposes the following results (•) and methodologies (▪):

- Insulating properties of alumina filled epoxy resin and SF_6 under DC voltage
    - Breakdown voltage: DC, LI, SI
    - Leakage current, surface and volume conductivities
    - Surface charge accumulation on SF_6/ alumina filled epoxy resin interfaces
    - Space charge accumulation in alumina filled epoxy resin
- Design criteria for HVDC GIS/GIL filled with SF_6
    - Electrode
    - High voltage conductor
    - Enclosure
    - Spacer surface
    - Electric field on metallic insert
    - Disconnector switch
- ▪ Electric field simulation methodologies for
    - ▪ HVDC GIS/GIL spacer
    - ▪ Surge arrester (new simplified method compared to conventional method using ATP and Flux)

3. Deliverables

3.1. Insulating properties

- Test report: 1053-vAA-Surface and volume conductivities of alumina filled epoxy resin vs environmental conditions
- Test report: 1305-vAA-Current through SF_6
- Test report: 14-P2-0401-003-Tenue en surface des isolants époxy sous contrainte 50Hz, DC et LI

- Test report : 1398-vAA-Surface dielectric strength of epoxy resin under different stresses
- Test report: 1849-vAA-Influence of various parameters on space charge in insulator made of epoxy resin
- PhD thesis: 1416-vAA-Dévelopment d'une méthode de mesure de charges d'espace appliquée aux isolateurs de poste sous enveloppe métallique
- Test report : 1737-vAA-Comportement de conduction des matériaux isolants dans les postes sous enveloppe métallique
- Litterature report : 14-P2-0401-001-Accumulation de charges à l'interface solide/gaz dans les postes sous enveloppe métallique
- Litterature report: Méthode de mesure de charges en surface
- Fiche technique : 2000-vAA-Characteristics of SF_6 gas and alumina filled epoxy resin for HVDC applications

3.2. Design criteria for HVDC GIS/GIL filled with SF_6

- Design criteria: 1031-vAA-SF_6 stress design criteria for HVDC GIS

3.3. Electric field simulation methodologies

- Report: 1343-vAA-Simulation guidelines for HVDC apparatus
- Fiche technique: 2001-vAA-Simulation methodology for solid spacer in HVDC GIS/GIL
- Fiche technique: 2002-vAA-Simplified electric field simulation methodology for surge arrester