DC time constant evaluation for HVDC GIS cable accessories

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ABSTRACT

To connect HVDC cables with each other and to substations like gas insulated metal enclosed switchgear (GIS), cable joints and cable connection assemblies need to be used. These components present a higher complexity than cables and GIS alone. Under DC voltage the electric field is changing over time, from a capacitive distribution to a resistive one. The time necessary for this transition is called DC time constant. This paper presents its evaluation through simulations in a cable GIS termination under different conditions, showing the importance of the AC-DC time constant knowledge for the determination of pertinent test program for these types of accessories.

KEYWORDS

HVDC Cable/GIS termination, modelling, DC time constant, S/IMP impulse

INTRODUCTION

High Voltage Direct Current (HVDC) transmission systems are becoming increasingly popular as a means of transmitting electricity over long distances with low losses with a cost effectiveness respect to AC systems. As result, they are used more and more for renewable energy integration, interconnection of power grids and long-distance transmission. For offshore renewable energy integration to onshore grid, for example, submarine cables are used and they need to be connected to the AC/DC converter stations. In offshore station where the surface and the volume of the platform represents high investment cost, it is important to optimize the surface and the technology of Gas Insulated Switchgear (GIS) shows particular interests thanks to its compactness and its insensitivity to the environment condition. To connect the HVDC submarine cables to the HVDC GIS, the most compact way is to use cable GIS termination. By reducing the surface area of the DC yard, significant cost savings of the offshore converter stations can be achieved, thereby optimizing the total investment cost. Thus, GIS cable connection assemblies are increasing of importance.

HVDC cable joints and cable/GIS termination components present a higher complexity than cables and GIS alone due to their geometry and to the presence of different solid and gaseous insulating materials in close contact. Moreover, it is known that the electric field stress under DC voltage cannot be easily estimated as under AC voltage and it depends on different parameters.

DC TIME CONSTANT

Under DC voltage the electric field distribution is more complicated to be accurately evaluated than in AC voltage. It is changing over time, starting from a capacitive distribution controlled by the permittivity of the insulating materials, to a resistive distribution, driven by the conductivities. The conductivities of the insulating materials usually have high dependences on the electric field and the temperature. Thus, the electric field under DC voltage have a close dependence on time, applied voltage and temperature. Moreover, the variations of conductivities between materials that are in close contact generate surface and space charges accumulation that in their turn can modify the electric field distribution. The time needed for the transition from capacitive to resistive electric field distribution is commonly known as DC time constant.

It is well known that for GIS the DC time constant can be very long in order of days to months depending on the geometry and insulating material conductivity. An example is given in Fig. 1. Usually for GIS the time constant is referred to $t_{90\%}$ so the time to reach the 90% of steady state. To evaluate this time, Eq.1 [1] is used for the estimation of the degree of charging $d_c(t)$ in a specific location. Where the E(t) is the variation of the electric field at a specific location and E_{AC} is the capacitive electric field at the energization, while E_{DC} is the steady state DC electric field at that location. When the 90% of degree of charging has been reached the transition time is considered reached.

$$d_c(t) = \frac{E(t) - E_{AC}}{E_{DC} - E_{AC}} \qquad \text{Eq.1}$$

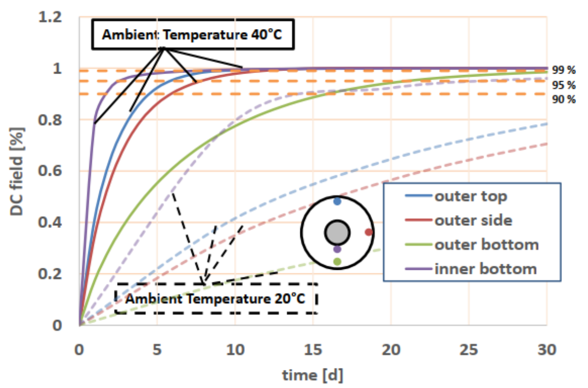

Fig. 1:Transition time for the insulator in a GIS, depending on the location and ambient temperature [1]

On the other hand, for cables alone the DC time constant is faster and generally in the order of some hours to days according to the temperature conditions [2], see the example in Fig. 2.

For GIS cable connection assemblies, due to the coexistence of different insulating materials in the insulating system, the DC time constant cannot be easily determined and it can be longer than the one for the cable alone. Accurate simulation models are thus needed in order to have a better understating and mapping of the AC-DC field transition in these types of accessories.