http : //www.cigre.org

2016 Paris Session

A2 PS3

Influence of the Lightning Impulse Shape on the Electrical Stresses on Windings Insulation of Power Transformers and Shunt Reactors

V. LARIN
All-Russian Electrotechnical Institute (VEI)
D. MATVEEV
Moscow Power Engineering Institute (MPEI)
Russia
vlarin@vei.ru

One of the crucial subjects of power transformers and shunt reactors of extra- and ultra-high voltage (EHV and UHV) design is the evaluation of their internal insulation electric strength. The dimensions of transformer equipment grow with increasing of the rated voltage. In order to design the transportable equipment it is inevitable to make significant complications of insulation structure, which yields the complication of overall design and of electric strength evaluation.

At the design stage the stresses are calculated with the help of specialized software and the permissible values – by methods based on the experimental studies of insulation electric strength. Determination of the electrical stresses comprises the calculation of voltage distributions along windings and corresponding electric field intensities. The specialized software is used to simulate impulse transients inside transformer windings under the application of full and chopped lightning impulses. These transients are oscillatory in nature which leads to the fact that voltages at different insulation gaps reach their maximum at different instants of time. In the report the specific gaps in the insulation of power transformers and shunt reactors are considered and corresponding instants of time for calculation of electric field are specified.

Usually the calculation of impulse transients in transformer or reactor windings is based on a number of assumptions. In particular the shape of the standard lightning impulse is supposed to be 1,2/50 μs for front/tail durations. However, in the test conditions, the unit under test (transformer or reactor) affects the applied voltage shape and parameters of the impulse differ from standard values. The report presents the results of calculations showing the influence of this difference in parameters values on the electrical stresses level.

A similar situation is with chopped lightning impulse. The IEC 60073-3 standard specifies that the chopped lightning impulse shall have a time to chopping between 2 μs and 6 μs and the geometric sizes of chopping circuit are not specified at all. However, the size of the chopping circuit determines the shape of the voltage applied to the unit under test and the frequency of oscillations after chopping, which have a significant influence on the electrical stresses on the longitudinal insulation as shown in the report by simulation.

In Russian national standards the sizes of chopping circuit are rated by means of specifying the range of distances between the spark gap and the tested unit of the particular rated voltage. The normalization of chopping loops gives greater certainty to the test centre staff, allows unifying the test procedure and preconditions the reproducibility of the test results. However, such normalization is not perfect, as it does not take into account the natural frequencies of transformer windings and the possibility of resonant processes in the windings, resulting in increased voltages on the longitudinal insulation if the frequency of the oscillations after chopping coincides with one of the resonant frequencies of the winding. Since the resonant frequencies of windings essentially depend on their design, different stresses on longitudinal insulation can be expected when transformers of different designs are tested by chopped lightning impulse with fixed frequency of oscillations at the tail. The report presents the comparison of stresses on transformer insulation under the application of chopped impulses with different parameters.

In the last edition of IEC 60060-1 there is a k-factor approach proposed to compensate for the overshoot at the front of the full lightning impulse. The approach is based on empirical data on the electric strength of the insulation models affected by standard full lightning impulse and by impulses with superimposed oscillations on the front. The application of k-factor approach allows to determine the equivalent (in the sense of dielectric strength) full lightning impulse test voltage and to tune away from superimposed oscillations, which often appear in the tests. However, for power transformers and shunt reactors the shape of the input voltage substantially determines the transients inside windings and particularly the voltages on the elements of longitudinal isolation. Despite all the advantages of this approach, it does not fully recognize the specifics of voltage oscillations inside windings of transformers and reactors, and therefore it is not entirely applicable to the transformer equipment. In the report the results of longitudinal insulation safety margins estimations are presented for the cases of full lightning impulse application with different overshoots at the front.