Lines of Further Research of Electromagnetic Processes in Transformers Under the Influence of Network Overvoltage

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Abstract – The lines of further research that will ensure an adequate reproduction of the internal resonance phenomena in the windings when a transformer is affected by the overvoltage of network.

Key words – transformer, overvoltage, internal resonance, frequency characteristics, methodology.

I. Main section

The methodology of any research must be consistent with the essence of the problem. Transformer is a distributed-constant object, in which between the longitudinal members of windings and between the windings of different phases there is mutual induction. In fact, the study of electromagnetic processes in transformers is a task for the study of the parameters of electromagnetic field existing in the environments with different electrical properties, on the boundaries of which certain (boundary) conditions are to be satisfied. The complexity of a quantitative mathematical description of the processes requires simplification of the primary physical problem to be addressed.

Damage to transformers at extra high voltage was attributed to the resonance in windings. Resonance characteristics of large transformers have been studied since the late 90s of the twentieth century. Since 2005, under the guidance of professor L. Nykonets, the study of internal resonance has been launched in Ukraine. Methodological problems were encountered when trying to study the parameters of electromagnetic processes in a randomly chosen particular point in the winding. The essence of the problem was that while attempting to realize the experimental frequency characteristics according to the canons of the Theoretical Foundations of Electrical Engineering, the standard parameter results, obtained by the synthesized mathematical models, *did not coincide* with the experimental results. Further research [1-8] solved the practical scientific problem, which resides in the development of a research methodology that represents a new level of knowledge, explains the reasons of the lack of reliability of the turn insulation, of inadequacy of the scientific advice, justifies the need to adapt the theory of electrical circuits with lumped parameters to solve a new class of problems, provides for an adequate reproduction of electromagnetic processes in transformer windings:

1. Analysis of the operating experience of transformers proved inadequate reliability of turn insulation. Engineering science, whose main recommendations are summarized in the present regulatory framework, cannot explain the causes of the inadequate reliability of turn insulation, and it is in the state of stagnation, because the research methods have exhausted themselves, and new effective approaches (methods) are absent.

2. Resonant frequencies of the frequency characteristics of any part of the winding are different from the resonance frequencies of the characteristics of the entire winding. Due to this, winding, as a distributed-constant line between the longitudinal members of which there is mutual induction, becomes heterogeneous.

3. The phenomena of internal resonance between structurally identical parts of the transformer winding are the most commonplace and obvious kind of excess voltage that always occurs. When there is excess voltage in transformer windings from the mains, inside the transformer there is also excess voltage, and its magnitude is radically greater than the applied magnitude.

4. Predecessors' isolated study of transformer magnetic fields without bounding to the electric field causes the magnetic field pattern that is different from the actual one.

5. The consequence of the heterogeneity of the distributed-constant line is the nonlinearity of voltage distribution along windings and their parts, violation of the principle of mutual induction in actual transformers, under the mutual magnetic fluxes in the disconnected windings or their parts – occurrence of resonance processes at the frequencies which are defined by both the frequency characteristics of the disconnected windings or their parts, and the frequency characteristics of the windings whose currents create mutual magnetic fluxes.

6. For the first time it is proved that the resonant frequencies of the processes occurring in the elements of transformer depend not only on the parameters of a transformer, but also on the parameters of the mains to which the transformer gives electricity.

7. Pulse actions on an operating transformer provoke occurrence of dangerous internal overvoltage.

8. Formulated basics of experimental research of source data and simulations that ensure adequate reproduction of electromagnetic processes in transformers' windings when exposed to the network overvoltage, including the methods of adaptation of the theory of electrical circuits with lumped parameters calculation to solve a new class of problems – research of the parameters of electromagnetic processes in the set volume points of the object with distributed parameters in the presence of mutual induction between the longitudinal elements of the winding.

9. All the research conducted without taking into account the provisions set forth above – including those on the basis of the well-known geometry of the design of transformers (the so-called "white box" model) – are theoretically inadequate.

10. The problem of resonance overvoltage in transformers is not a problem of CIGRE, but of IEC, which has to set reasonable standards for testing the longitudinal insulation of transformers.

Implementation of the abovementioned provisions requires the efforts of experts of different profiles and areas of focus.

The above-stated implies an urgent need to develop an international program concentrated on improving the reliability of winding insulation of transformers. This program should provide for:

- determining the frequency characteristics of transformers of *all* sizes and *all* nominal voltages (as passport characteristics of equipment);
- adapting of the existing program complexes to address a new class of problems;
- development of mathematical methods to implement the frequency characteristics;
- study of the correlation between the current characteristics of insulation and the possible frequency of resonance overvoltage;
- development of the theory of calculating the scattering fields in transformers from the standpoint of a single electromagnetic field existence in order to determine the resistance of individual windings' and their parts' scattering;
- justification of the testing specification of the electric strength of winding insulation.

Conclusion

After a long period of stagnation and after identification of the key inconsistencies that cause it, the dialectics of development of the power engineering requires effective active actions to improve the reliability of winding insulation of transformers.

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