The Operation of Current Transformer with Open Secondary Circuit

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Abstract – Disconnection of current transformer secondary circuit is accompanied by the appearance on the terminals of its secondary winding high-voltage pulses which are dangerous for isolation of a current transformer, its secondary circuit equipment and attending personnel.

In the paper analysis of operating modes of current transformers with open their secondary circuits is carried out.

The comparative analysis of calculation results of amplitudes of voltage pulses on the open secondary winding terminals of current transformer type TLM-10 (ТЛМ-10), which have been obtained by using computer simulation of its emergency operating mode and analytical calculations, is carried out.

Key words – current transformer, secondary circuit, disconnection, high-voltage pulse, overvoltages, calculation scheme, methods of analytical calculations.

I. Introduction

Current transformers operate in both steady-state and transient operating modes of electrical networks. In such modes they should provide corresponding characteristics and accuracy of primary current transformation.

The opening of current transformer secondary circuit is accompanied by the sharp increase of magnetic flux in the magnetic core as a result of disappearance of demagnetizing magnetomotive forse of the secondary winding that will cause an increase of active losses in the magnetic core, its overheating and, as a result, insulation damage of windings and in the end – a failure of the current transformer.

Besides, the magnetic flux induces in the secondary winding of current transformer high-voltage pulses with an amplitude which can achieve values of several kilovolts (in contrast to several tens of volts in the normal mode). Such overvoltages on current transformer secondary winding terminals cause, as a rule, insulation damage of secondary current circuits, relaying and automation systems, especially modern microprocessor devices, which are connected to this winding. Also they can cause an electrical injury of attending personnel.

Therefore the questions of safety service of current transformers and a designing of the reliable protection methods from overvoltages after the opening their secondary circuits are extremely topical.

In the literature the operation modes of current transformers with open their secondary circuits aren't widely investigated. Only in [1-4] such modes are described and in [1, 3, 4] some possible methods for current transformer protection from operation with open secondary circuit are proposed. But there are no such efficient current transformer protection devices in our electric power systems.

II. The Results of Research

For the simulation and analysis of various operating modes of current transformers in specialized computer program "RE" [5] the calculation schemes of single-stage and cascade current transformers has been created. They consist of few units, each of them simulates certain parameters and characteristics of the transformer, which is investigated.

In the paper the operation mode of current transformer type TLM-10 (ТЛМ-10) (Fig. 1) with open its secondary circuit is analysed. The calculation model of this transformer has been created in program "RE" with purpose of computer simulation its operation in such mode.

Fig. 1. Current transformer type TLM-10 (ТЛМ-10)

The current transformer type TLM-10 (ТЛМ-10) is a small-size current transformer with cast insulation and rated voltage 10 kV, rated primary current 1500 A AC and rated secondary current 5 A AC.

Transformer is designed as a supporting construction with two magnetic cores, one primary and two secondary windings.

The calculation scheme of current transformer type TLM-10 (ТЛМ-10) is shown on Fig. 2.

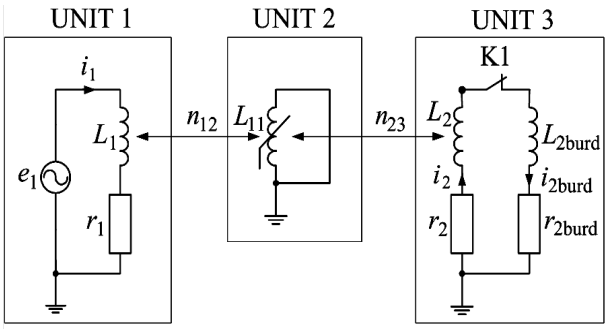


Fig. 2. Calculation scheme of current transformer type TLM-10 (ТЛМ-10)

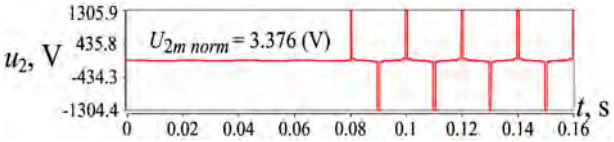
The unit 1 of scheme simulates a primary circuit of current transformer. In unit 2 the magnetization curve of transformer magnetic core is simulated (non-linear inductance L_{11}). In the program "RE" magnetic characteristic is set by the reductive to a primary circuit weber-ampere characteristic $\Psi_1 = f(i_{exc.})$, which has been calculated from experimental obtained volt-

ampere characteristic of current transformer type TLM-10 (TJIM-10).

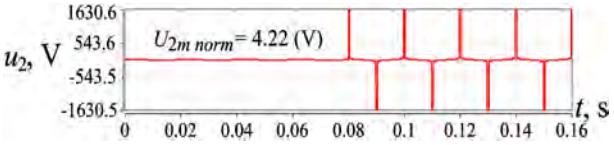
The unit 3 simulates parameters of transformer secondary winding (r_2, L_2) and its secondary burden (r_{2burd}, L_{2burd}). The disconnection of secondary circuit is carried out by a switch K1.

A coupling factor n_{12} between first and second units is equal to unity and the coupling factor n_{23} between second and third units is equal to rated transformation ratio of current transformer type TLM-10 (TJIM-10).

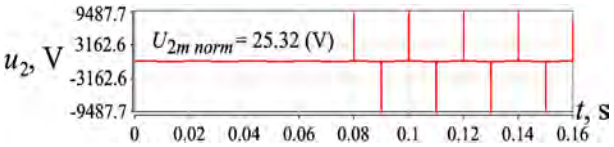
On Fig.3 the oscillograms of secondary voltage of transformer type TLM-10 (TJIM-10) before and after opening its secondary circuit for various values of primary current are shown. The disconnection is carried out at the time 0.08 sec, when sinusoid curves of transformer primary and secondary currents flow through the zero value. The voltage $U_{2m\ norm}$ characterizes the amplitude value of secondary voltage of current transformer type TLM-10 (TJIM-10) in normal before opening its secondary circuit operation mode.



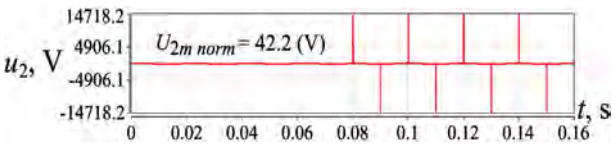
a) $I_1 = 0.8I_{1rat} = 1200$ (A)



b) $I_1 = I_{1rat} = 1500$ (A)



c) $I_1 = 6I_{1rat} = 9000$ (A)



d) $I_1 = 10I_{1rat} = 15000$ (A)

Fig. 3. The oscillograms of secondary voltage of current transformer type TLM-10 (TJIM-10) before and after opening its secondary circuit

After opening secondary circuit of current transformer the voltage on its secondary terminals sharply increases in comparison with normal operation mode and its curve becomes non-sinusoidal in the result of trapezoidal curve of magnetic flux in transformer magnetic core during its saturation.

For current transformer type TLM-10 (TJIM-10) the voltage amplitude on the open secondary winding terminals reaches value 1305.9 V already for a primary current which is equal to 1200 A. As is shown on Fig. 3, in the normal operation mode secondary voltage is equal to 3.376 V.

As is shown in [6], the value of test voltage for secondary circuits of current transformers in operation conditions is equal to 1000 V.

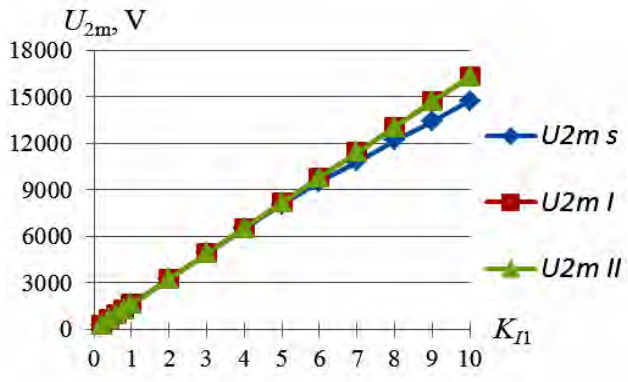


Fig. 4. The dependence of voltage amplitudes on open secondary winding terminals of current transformer type TLM-10 (TJIM-10) on multiplicities of its primary current

Such high voltage levels on the open transformer secondary winding terminals cause a dangerous factor during all operation time of current transformers. So the main purpose of our researches is to design effective and reliable their protection systems from overvoltages in such operation modes.

On Fig.4 the dependence of voltage amplitudes on open secondary winding terminals of current transformer type TLM-10 (TJIM-10) on multiplicities of its primary current is shown, which has been obtained by using computer simulation of transformer emergency operation mode (*U2m s*) and the methods of analytical calculations (method 1 – *U2m I* and method 2 – *U2m II*).

Conclusion

The results of research have theoretical and practical significance for further analysis of operation modes of current transformers with open their secondary circuits with purpose of creating effective and reliable protection systems from overvoltages in such modes.

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