The Operation Mode of Single-Stage Current Transformer with Open Secondary Circuit

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Abstract – The operation mode of current transformer with open secondary circuit is emergency and is accompanied by the appearance on the terminals of its secondary winding overvoltages, which are dangerous for secondary equipment and attending personnel.

In the paper analysis of operation mode of single-stage current transformer type TV-35 (TB-35) after disconnection of its secondary circuit is carried out.

The influence of active losses in magnetic core of current transformer TV-35 (TB-35) on the values of its secondary overvoltages is investigated.

Key words – current transformer, secondary circuit, disconnection, terminals of secondary winding, high-voltage pulses, overvoltages, magnetic core, active losses.

I. Introduction

The current transformers (CTs) in electric power systems carry out important functions as a sensor of input information for measuring equipment, relay protection and automatic devices. Therefore they should provide corresponding accuracy classes of primary current transformation in both steady-state and transient operation modes of power systems.

The operation mode of CT with open its secondary circuit is emergency. In this mode the sharp increase of magnetic flux in the magnetic core of CT is observed as a result of disappearance of demagnetizing magnetomotive forse of the secondary winding. It 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 CT.

Also the magnetic flux, which flows in the magnetic core in this mode, induces on the terminals of secondary winding of CT high-voltage pulses, which are dangerous for CT, an equipment of its secondary circuits and also for attending personnel, who works in this circuits.

In the literature the modes of disconnection of secondary circuits of CTs aren't widely investigated. Such modes are described in [1–6] and there possible methods for CT protection from secondary overvoltages are proposed. But there are no efficient and reliable CT protection devices from overvoltages, which make impossible the equipment damage and an electrical injury of attending personnel, in our electric power systems.

The incidents of damage of CTs in such modes and also the incidents of personnel death due to induction of high voltage (over 1 kV) in secondary circuits are describes in [3].

The purpose of research is a comprehensive analysis of emergency mode of opening the CT secondary winding and design using the results of research and putting into service reliable its protection device from overvoltages.

II. The Results of Research

For investigation of operation modes of CTs the computer simulation of their calculation schemes in the software complex "RE" [7] is applied. This program can simulate steady-state and transient operation modes of power system equipment.

In the paper the values of overvoltages on the secondary winding terminals of CT type TV-35 (TB-35) without and with taking into account active losses in its magnetic core are investigated.

The CT type TV-35 (TB-35) are placed in high-voltage bushings of breakers and transformers and consists of a toroidal magnetic core with wound around it secondary winding.

The calculation scheme of CT with taking into account simulation of active losses in its magnetic core in the program "RE" is shown on Fig. 1.

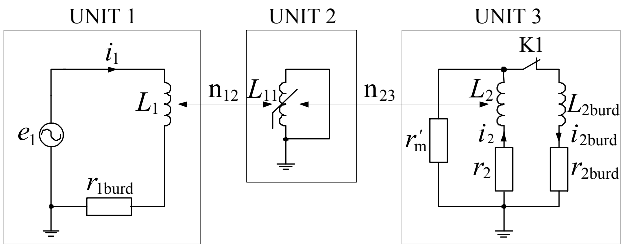
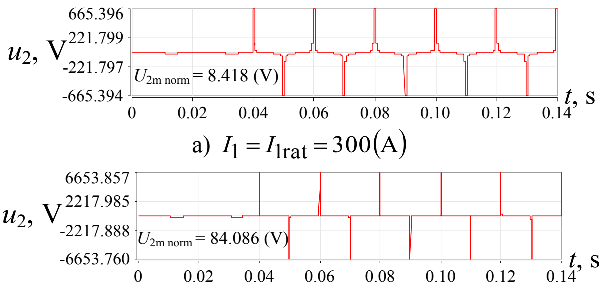


Fig. 1. Calculation scheme of CT type TV-35 (TB-35) with taking into account magnetic losses

The unit 1 of scheme simulates a primary circuit of CT. In the unit 2 the magnetization characteristic $\Psi_1 = f(i_{exc.})$ of transformer magnetic core is simulated (non-linear inductance L_{11}). In the unit 3 parameters of transformer secondary winding (r_2, L_2), its secondary burden (r_{2burd}, L_{2burd}) and reduced to a secondary side resistance r'_m, which describes magnetic losses, are simulated.

A coupling coefficient n_{12} is equal to unity and the coupling coefficient n_{23} is equal to rated transformation ratio of CT.

On Figs. 2 and 3 the oscillograms of secondary voltage of CT type TV-35 (TB-35) before and after opening its secondary circuit without and with taking into account active losses in its magnetic core, respectively, are shown.



a) $I_1 = I_{1rat} = 300(A)$

b) $I_1 = 10 \cdot I_{1rat} = 3000(A)$

Fig. 2. Calculation oscillograms of secondary voltage of CT type TV-35 (TB-35) before and after opening its secondary circuit without taking into account magnetic losses

On Fig. 4 the dependence of voltage amplitude on open secondary winding terminals of CT type TV-35 (TB-35) on multiplicity of its primary current relatively to the rated value without and with taking into account active losses in transformer magnetic core is shown.

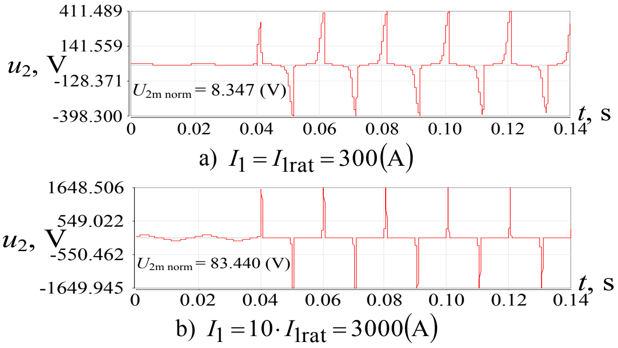


Fig. 3. Calculation oscillograms of secondary voltage of CT type TV-35 (TB-35) before and after opening its secondary circuit with taking into account active losses in its magnetic core

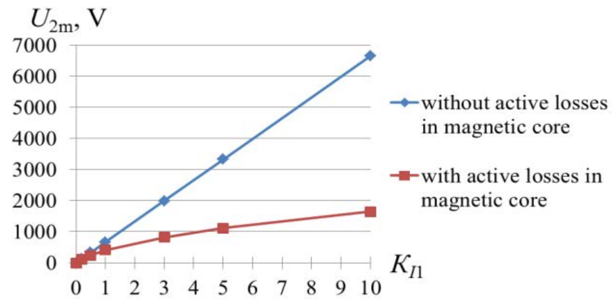


Fig. 4. The dependence of voltage amplitude on open secondary winding terminals of CT type TV-35 (TB-35) on multiplicity of its primary current

As is shown, for rated primary current the voltage value on open secondary winding terminals of CT is not dangerous for equipment (is not more than 1 kV), but for current $I_1 = 10{*}I_{1rat}$ the secondary voltage amplitude is equal 6654 (V) in the mode without taking into account magnetic losses and 1650 (V) with taking into account magnetic losses.

On Fig.4 is shown, that in the calculation mode without taking into account active losses in magnetic core of CT the voltage amplitude on open secondary winding terminals of transformer depending on the multiplicity of primary current relatively to its rated value increases linearly.

For calculation the values of secondary overvoltages in CT with taking into account active losses in its magnetic core the divergence between results for the increase of multiplicity of transformer primary current compared with first mode is observed. For multiplicities of primary current up to rated value the divergence between results is small. For larger multiplicities of primary current of CT the divergence between results significantly increases and for the primary current $I_1 = 10{*}I_{1rat}$ the amplitude of secondary voltage, which is calculated with taking into account active losses in magnetic core, is approximately 4 times less than amplitude, which is calculated without taking into account active losses.

This is because for large multiplicities of primary current the voltage pulses are very short-term (compared with pulses for small multiplicities of current) and they are cut by the demagnetization of magnetic core by the eddy currents during the quick change of flux linkage in magnetic core. The voltage pulses for small multiplicities of primary current (up to rated value) have a longer duration and therefore the influence of magnetic losses on them is much less (the flux linkage in the core changes relatively slowly). As is shown in [5], the duration of secondary voltage pulse depends on the value of primary current of CT.

Conclusion

Active losses in magnetic core of CT significantly affect on the values of its secondary overvoltages, especially for large multiplicities of primary current. Such modes more accurately describe electromagnetic processes in magnetic core of CT and reflect results.

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