Operation Modes of Protection System of Current Transformers Against Secondary Overvoltages

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Introduction

The disconnection of the secondary circuit of current transformer is an emergency mode of its operation. Due to the disappearance of the demagnetizing magnetomotive force of the secondary winding, the magnetic flux and the losses of active power in the magnetic core increase significantly. It, in the long term, can damage the insulation of the magnetic core and the windings. In the end, it can damage the current transformer. In addition, the magnetic flux induces high voltage pulses in the secondary winding of current transformer, which can destroy the equipment insulation and can lead to electric shock to the maintenance personnel.

Known methods of protection of current transformers against overvoltages

The authors in their papers propose the protection systems of current transformers against secondary overvoltages, which are based on the connection to the terminals of the secondary windings the special protection devices when the dangerous overvoltages have occurred: the protection device with a special electromagnetic balanced relay; the device with the zener diodes that are connected to the secondary terminals of current transformers; the protection device with a triac and bi-directional dinistor; the protection with a special two-position polarized relay with manual return and auxiliary semiconductor elements to provide the operation of this relay; the system with a bi-directional diode and a thermo contact; the device with the semiconductor high-speed controlled thyristor switches; the protection system with a varistor and a thermal relay.

However, in our opinion, the main disadvantages of the mentioned above protection devices of current transformers against secondary overvoltages are:

1) the absence of electrical separation of the secondary circuits of current transformers and the circuits of protection devices, which causes a possible leakage of a secondary current into the protection circuits in the normal operation mode of current transformer. It is unacceptable, especially for the current circuits of commercial metering systems of electricity consumption. It also increases the probability of the damage of circuit elements of the protection devices (capacitors, semiconductor elements, etc.) from the secondary overvoltages. As a result, the protection system will not operate;

2) the significant heating of the structure of the semiconductor elements due to the operation of the protection devices due to the long flow of a current through them;

3) the great cost and the great size of the protection devices.

Protection system of current transformer against secondary overvoltages

We have offered a protection system against the action of overvoltages with values above 1000 V, which arise at the terminals of the secondary winding of current transformer after disconnection its secondary circuits. In the protection system to limit the level of overvoltages at the terminals of the secondary winding, a breakdown fuse type PP-A/3 (ПП-А/3) is used as the surge arrester (the trigger voltage of the fuse is 351-600 V, 50 Hz) (Fig. 1). The breakdown fuse withstands a current of 200 A, 50 Hz after the breakdown for a maximum time of 30 min. A low-inductive concrete resistor is connected in series with the fuse. After the breakdown of the fuse a voltage is generated on the resistor to start the shunting signaling device of the protection system, which in turn by means of the corresponding contacts of the electromechanical relay connects the terminals of the secondary winding of current transformer and triggers the substation alarm system.

Fig.1. Breakdown fuses type PP-A/3 (ПП-А/3)

Fig. 2 shows the calculation scheme for simulating the operation modes of the protection system of current transformer type TSHL-20 (ТШЛ-20) with a primary rated current I_{1rated}=10000 A in the software complex "FASTMEAN".

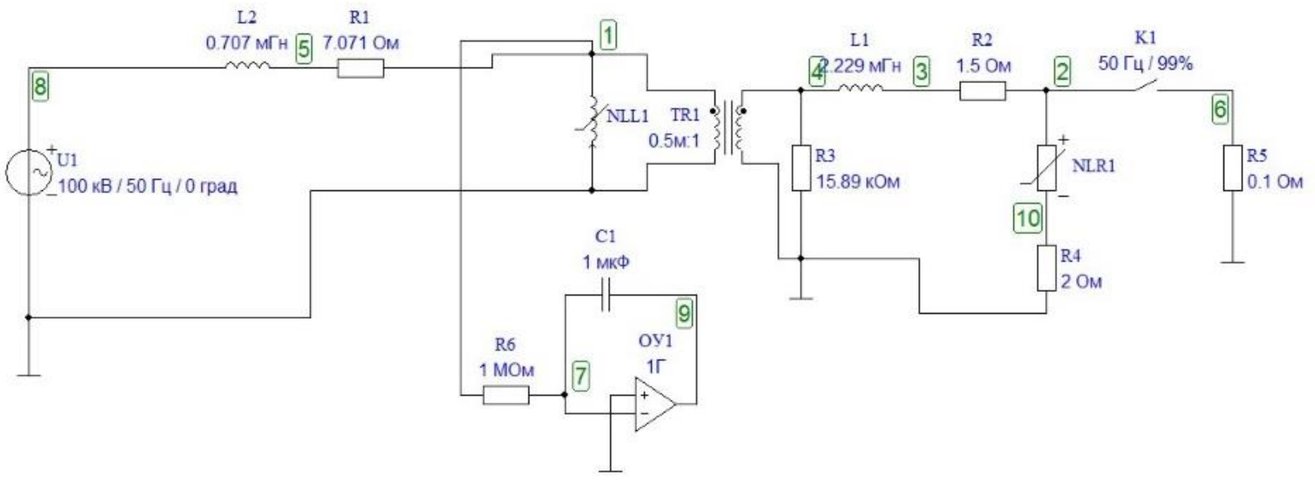
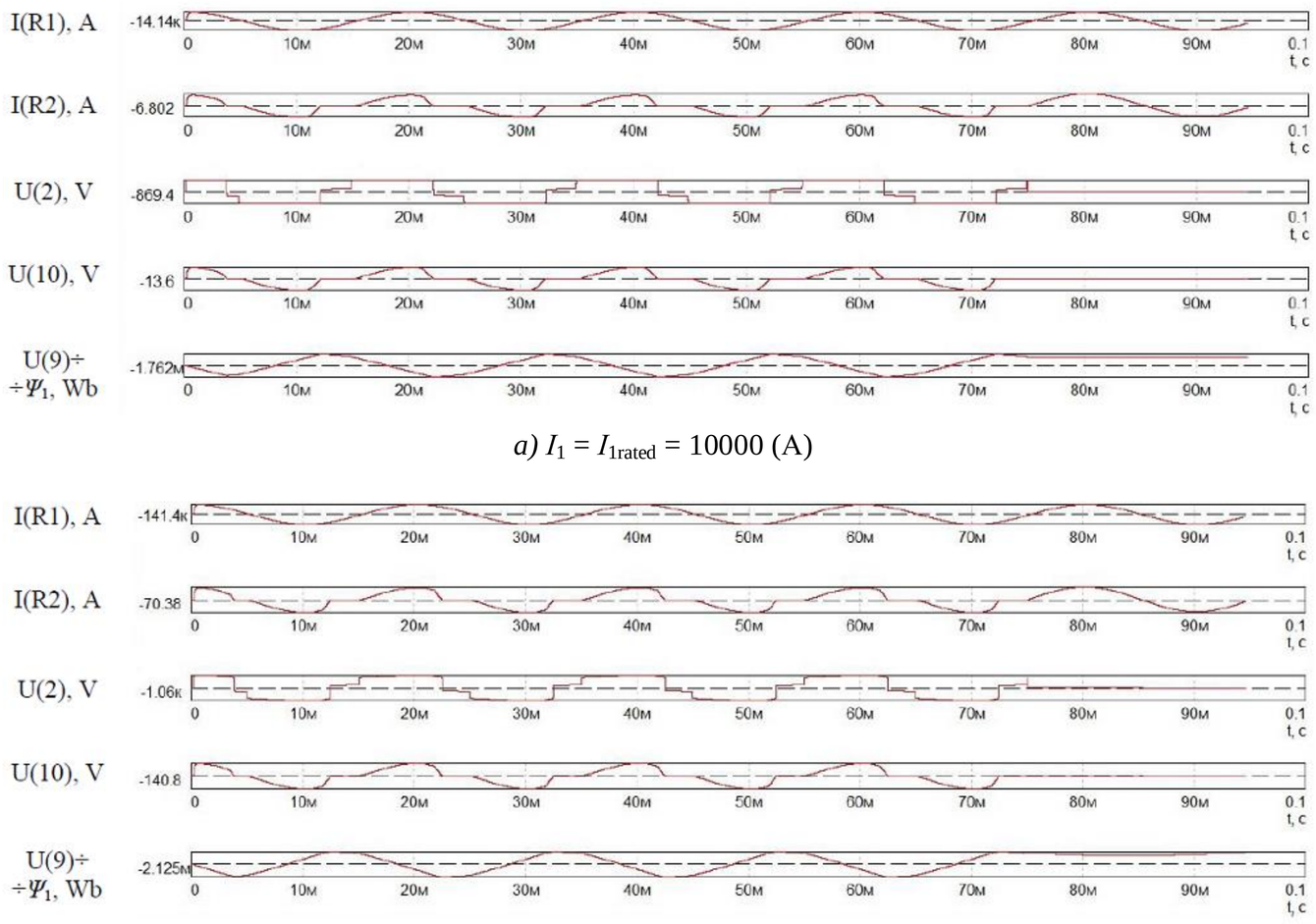


Fig.2. Calculation scheme for simulating the operation modes of the protection system of current transformer type TSHL-20 (ТШЛ-20)



a) $I_1 = I_{1rated}$ = 10000 (A)

b) $I_1 = 10 \cdot I_{1rated}$ = 100000 (A)

Fig.3. Calculated oscillograms of the operation modes of protection system of current transformer type TSHL-20 (ТШЛ-20) with open its secondary circuit:

I(R1) – the primary current of current transformer;
I(R2) – the current in the secondary winding of current transformer;
U(2) – the voltage at the terminals of the secondary winding of current transformer;
U(10) – the voltage drop across the low-inductive resistor of protection system;
U(9) ÷ Ψ_1 – reduced to the primary side a magnetic flux linkage of the secondary measuring winding of current transformer

For both the nominal and ten times currents of current transformer type TSHL-20 (ТШЛ-20) with open secondary circuit the surge arrester limits the voltage U(2) at the terminals of the secondary winding to the calculated operation value of the breakdown fuse type PP-A/3 (ПП-А/3). Due to the large ampere-turns of the primary current and the "powerful" magnetic core of current transformer TSHL-20 (ТШЛ-20) its core is symmetrically magnetized during almost the entire period of sinusoidal current with small areas of core saturation. The current protractedly flows through the surge arrester during the duration of primary current period (during the total time ~ 0.01 s). In such operation modes of protection system a significant load of the breakdown fuse should be expected. The current pulses in the secondary winding continue until the contacts of the electromechanical relay close the terminals of the secondary winding. Then the secondary current I(R2) becomes sinusoidal and proportional to the primary current I(R1) taking into account the transformation factor of current transformer.

The efficiency and reliability of the operation of proposed protection system of current transformers against secondary overvoltages were also confirmed by the results of a laboratory experiment with the current transformer type TLM-10 1500/5 (ТЛМ-10).

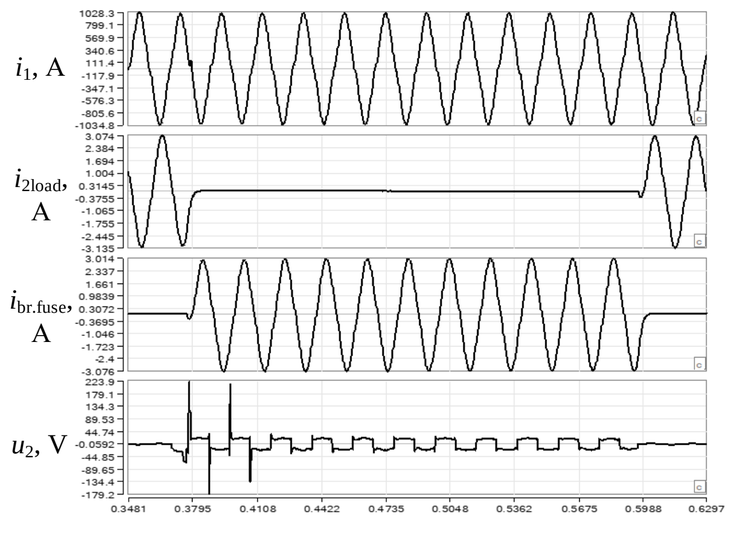


Fig.4. Laboratory oscillograms of the parameters of the operation mode of protection system of current transformer type TLM-10 (ТЛМ-10) with the breakdown fuse type PP-A/3 (ПП-А/3)

Fig.5. Carrying out the laboratory experiments with the protection system against overvoltages and the current transformer type TLM-10 (ТЛМ-10)