E3S Web of Conferences **461**, 01064 (2023) https://doi.org/10.1051/e3sconf/202346101064
RSES 2023

Digital protection of electrical equipment in railway transport

Komolbek Turdibekov[1]*, *Dilshod* Rustamov[1], *Sarvar* Xalikov[1]

[1]Tashkent State Transport University, 100167, Tashkent, Uzbekistan, Temiryulchilar street, 1 st

Abstract. In this scientific study, an analysis of the modernization of the digital protection of AC traction substation electrical equipment in operation, in particular power transformers, the implementation of the basic provisions for the implementation of digital protection of power transformers, finding algorithms for the implementation of both measuring and logic elements of digital protection, mathematical models of digital protection of power transformers are obtained, a method for blocking current protection is implemented, a method is selected finding the setpoints of the stage, obtaining differential protection, the schemes of secondary switching of digital protection are considered, the results of the scientific research carried out in the microprocessor terminal of protection of power transformers.

1 Introduction

The development of modern technologies in the railway power supply system for digital protection of electrical equipment of an alternating current traction substation, in particular power transformers, provides for the following tasks: differential current protection, maximum voltage current protection, external protections that control the state of the power transformer, automatic re-activation of the power transformer, automatic switch control with the function of a switch failure backup device. One of the responsible and difficult to implement stages of protection of power transformers is differential current protection, as well as maximum current protection.

Analysis of microprocessor protection of a power transformer provides the following set of functions: differential current protection, which includes a differential current stage with braking and a differential current stage without braking; eight stages of maximum current protection with voltage starting capability; directional action and connection to any side of the transformer, six stages from increasing the zero or negative sequence current with the possibility of starting by voltage, directional action and connection to any side of the transformer, four stages of maximum and four stages of minimum voltage with the possibility of return at the rate; four stages of maximum and four stages of minimum frequency with the possibility of return at the rate; sixteen external protections that monitor the state of the transformer using external signals; automatic transfer of reserve, automatic re-switching of the transformer.

Modernization of these stages can significantly increase the reliability of digital protection of the power transformer, increase the sensitivity of the magnetization current to voltage, algorithms for adjusting differential current protection from equilibrium currents of external short circuits based on correct transform intervals, in particular, develop a criterion that reacts to external signs. no matter a short circuit of the current size, which does not require the calculation of setpoints.

2 Experimental research

The formation of the path of orthogonal components of the digital microprocessor protection consists of an input sensor, a 2nd order analog filter on an operational amplifier, an analog-to-digital converter, as well as a digital filter, the filtration frequency is calculated by the following formula.

$$f(k) = \frac{k}{N} f_c \tag{1}$$

where k is the harmonic number
N – the number of samples
f_c – sampling rate
The algorithm formula for the kth harmonic has the form

* Corresponding author: ilider1987@yandex.ru

$$X(t) = \left[cos\left(\frac{2\pi}{N}k\right)\vartheta_{N-1} - \vartheta_{N-2}\right] - sin\left(\frac{2\pi}{N}k\right)\vartheta_{N-1} \quad (2)$$

$$\vartheta_1 = x_1 + 2\,cos\left(\frac{2\pi}{N}k\right)\vartheta_{N-1} - \vartheta_{N-2} \quad (3)$$

Where x_1 is the *i*th sample of the signal $0 \leq i \leq N-1$

Coefficients $\vartheta_2 - \vartheta_1 = 0$

A study using a computational experiment method showed that the path for forming controlled quantities makes it possible to implement filtering of the 1st, 2nd and 5th harmonics during one period of industrial frequency, which is sufficient for the implementation of measuring elements of transformer protection stages. The 1st harmonic filter is precisely tuned to a frequency of 50 Hz, but in the operating frequency range (47-52 Hz) it has an error of up to 3%. To ensure sufficient filtering accuracy, it is necessary to change the number of samples per period when the network frequency changes. The 2nd harmonic filter completely suppresses all harmonics, producing a 100 Hz output signal without attenuation or amplification. When filtering the 5th harmonic, the signal is attenuated to 97% due to the action of the analog filter. When implementing differential current protection of a transformer, the attenuation of the 5th harmonic must be taken into account using a correction factor of 1.03.

From false alarms of differential current protection against external short circuits, a new blocking method has been developed, which implements the ratio of increments of differential and braking currents according to the evaluation. This method is relatively easy to implement while maintaining the necessary accuracy and does not require special attention to the computing power of the digital protection terminal.

The functional scheme of blocking differential protection in case of external short circuits is given in Figure 1.

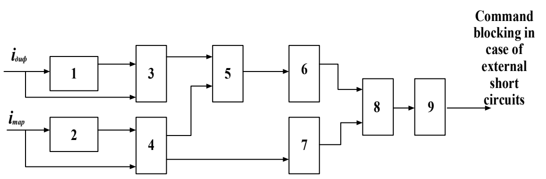

Figure 1. Functional diagram of blocking differential current protection in case of external short circuits

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Blocks 1 and 2 implement the memorization and storage of the two previous samples of the differential i_{dif}. and i_{brk}. braking currents.

Blocks 3 and 4 determine the increment on two sampling periods of differential and braking currents. Block 5 calculates the ratio of increments of differential and braking currents on two sampling periods. Block 6 compares the above ratio with the coefficient K on two sampling periods. The coefficient K is selected from the range 0.2-0.3.

The functional scheme of blocking current protections against magnetization current surges (Figure 2) contains: frequency filter 1 of the first harmonic of the current, frequency filter 2 of the second harmonic of the current, filters 3 and 5 of the direct sequence of the current, filter 4 of the reverse sequence of the current, block 6 of blocking based on current control $I_{1пр}$, block 7 of monitoring the content of the reverse current sequences of the first harmonic, block 8 of calculation and control of the parameter when the magnetization current is thrown $I_{2пр}$. / $I_{1пр}$., element 9 logical "And", element 10 "Prohibition".

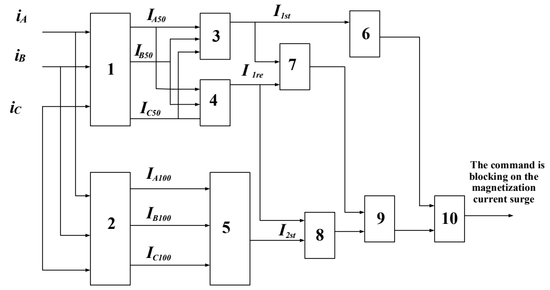

Figure 2. Functional diagram of blocking current protections during a surge of magnetization current.

As a result of each experiment of switching on an unloaded power transformer, the time dependences of the blocking parameters were obtained.

Blocking during magnetizing current surges is implemented in phase-by-phase or cross-phase modes; in the second case, the activation of the blocking in any phase leads to blocking of the other two.

The range of changes in the minimum value of the blocking parameter was 67.2-112.2%, the range of changes in the minimum value of the cross-blocking parameter was 40.3-117.1%. Thus, the blocking parameter is more stable and more effective at detecting inrush currents than the cross-blocking parameter.

In the initial period, during a short circuit, the transformer operates in saturation mode, and 10 ms after the occurrence of a short circuit, the measuring element of the differential stage is activated with braking. This is due to the phase reduction of the low side currents. Blocking signals for external short circuits, occurring 2 ms after the start of the short circuit, prohibit the operation of the differential current protection.

Blocking signals exist throughout the entire duration of the external short circuit, which ensures reliable detuning from unbalance currents.

Studies of differential current protection in external short circuit modes have revealed: differential current protection does not operate in the specified modes, the response time of the blocking algorithm in the event of an external short circuit is no more than 2 ms.

The use of a blocking algorithm for magnetizing current surges ensures unblocking of differential current protection in the event of significant fault currents.

Studies of differential current protection in internal short circuit modes have shown: differential current protection of a transformer operates reliably in internal short circuit modes, while its own response time does not exceed 30 ms; the use of a blocking algorithm during magnetizing current surges does not slow down the operation of differential current protection during internal short circuits. damage.

The mathematical model of differential current protection includes models of input current sensors and a second order analog filter, phase and amplitude reduction of currents, calculation of braking and differential currents, blocking from overexcitation of a power transformer, calculation of differential cutoff, blocking algorithm from external short circuits, blocking algorithm from magnetization current surges.

The mathematical model of the maximum current protection includes models of input current sensors and a second order analog filter, a model of a digital filter of orthogonal components, a blocking algorithm when a magnetization current is thrown.

3 Research result

The study of the maximum current protection in short circuit modes shows:

-the protection of the power transformer reliably operates in short-circuit mode, while its own response time does not exceed 30 ms;

-the application of the blocking algorithm during magnetization current surges does not slow down the operation of the maximum current protection in case of internal damage.

4 Conclusion

The functional scheme of the microprocessor protection terminal of the power transformer has been developed, which includes 12 current, 4 voltage and 26 discrete inputs and provides control of up to three arms of the protected power transformer. The input current and voltage signals are converted on the input sensors into voltage signals, which are converted into a digital signal on a 16-bit analog-to-digital converter.

Based on the data obtained, the operation of differential current protection and maximum current protection is realized.

Application. The developed digital protections were put into trial operation at the Tashkent power supply distance ECH -1 of Uzbekistan Temir Yullari AO.

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