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ИССЛЕДОВАНИЕ МИКРОПРОЦЕССОРНОЙ ТОКОВОЙ ЗАЩИТЫ ТРАНСФОРМАТОРА В РЕЖИМАХ КОРОТКИХ ЗАМЫКАНИЙ

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INVESTIGATION OF MICROPROCESSOR TRANSFORMER CURRENT PROTECTION IN SHORT CIRCUIT FAULT MODES

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Представлено исследование токовой защиты трансформатора с блокировкой от броска тока намагничивания в режимах коротких замыканий. Показано, что предлагаемый алгоритм блокировки от броска тока намагничивания может быть применен в микропроцессорных токовых защитах трансформаторов.

Ключевые слова: блокировка от броска тока намагничивания, токовая защита.

Ил. 5. Библиогр.: 3 назв.

The paper presents an investigation on transformer current protection with blocking against magnetizing in-rush current in short circuit fault modes. It has been shown that the proposed magnetizing in-rush current blocking algorithm can be implemented in microprocessor current protections of transformers.

Keywords: magnetizing in-rush current blocking, current protection.

Fig. 5. Ref.: 3 titles.

The paper presents investigation of transformer current protection with inrush blocking algorithm during fault processes. Results of the previous series of experiments [1] showed that proposed inrush blocking algorithm provides the higher sensitivity to inrush currents than classical inrush blocking algorithm which is based on the presence of the second harmonic into the phase currents.

The investigation was performed by computer simulation method using mathematical models of transformer and overcurrent protection. The mathematical model of transformer was validated on the basis of the comparison with the results obtained in a field experiment [2].

Investigation includes simulation of various fault types on the 10 and 110 kV bushings of the 6.3 MV·A reducing transformer. The overcurrent stage with proposed inrush blocking algorithm was realized in 1-millisecond cycle for the reason of a detailed study.

The inrush blocking algorithm for overcurrent protections [1] estimates the ratio of the positive sequence current of the second harmonic $I_{2h\text{-}pos}$ to the negative sequence current of the first harmonic $I_{1h\text{-}neg}$ when the negative sequence current of the first harmonic $I_{1h\text{-}pos}$ is high enough. The blocking signal is generated if the positive sequence current of the first harmonic does not exceed the value of the inrush current.

During the computer simulation experiments the fault oscillograms (Fig. 1–5) were obtained. The oscillograms contain the following signals:

- I_A, I_B and I_C – secondary currents of current transformers (CT) which are installed in the 110 kV side of the power transformer in the *A*, *B* and *C* phases correspondingly;
- signals *SG_A*, *SG_B* and *SG_C* show that the value of the second harmonic current is higher than 15 % in *A*, *B* and *C* phases correspondingly;
- signal *SG_po* shows that ratio $I_{2h\text{-}pos}/I_{1h\text{-}neg}$ is higher than 15 %;
- signal *Kop* forbids inrush blocking when $I_{1h\text{-}neg}/I_{1h\text{-}pos}$ is lower than 25 %;
- signal *Kdb* forbids inrush blocking when $I_{1h\text{-}pos}$ is higher than 8 rated currents of the power transformer;
- *Blk* – inrush blocking signal of the current protection;
- *MU_A*, *MU_B* and *MU_C* – current protection measurement units of the *A*, *B* and *C* phases correspondingly. Signal shows that phase current is higher than 1.5 rated current of the power transformer;

• *Trip I > A*, *Trip I > B* и *Trip I > C* – overcurrent protection tripping operation of the *A*, *B* and *C* phases correspondingly. Overcurrent protection tripping signal is formed when two consecutive measurement unit signals occur and there is no blocking signal *Blk*.

During single-phase fault at the 110 kV transformer bushings (Fig. 1) CT in the *A* phase operates in a saturation mode which leads to the second harmonic appearance (signal *SG_A*) into the current I_A. The ratio $I_{2h\text{-}pos}/I_{1h\text{-}neg}$ has the value higher than 15 % and signal *SG_po* is formed. During single-phase fault the current $I_{1h\text{-}neg}$ has a high level and the signal *Kop* is not formed. A high level of the fault current determines the appearance of the signal *Kdb* which forbids the blocking signal *Blk* formation.

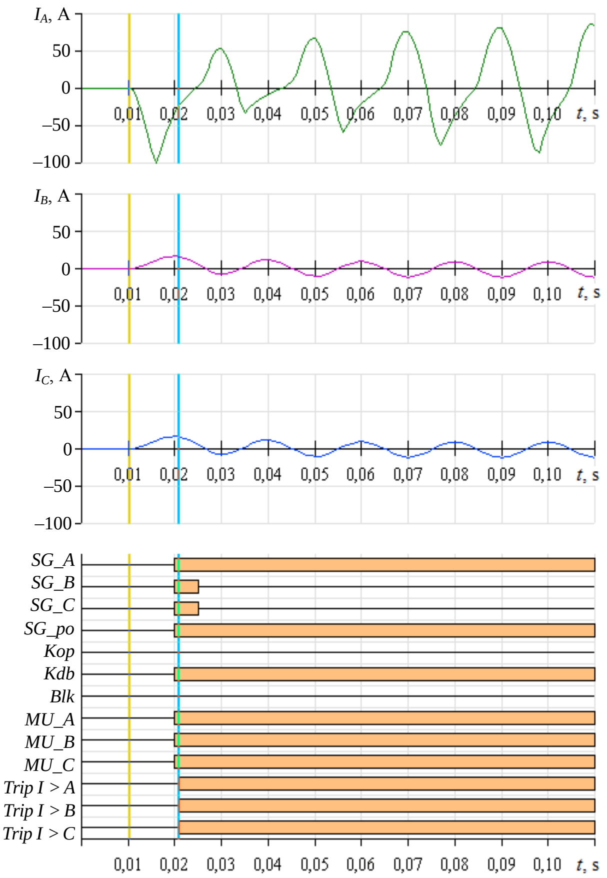

Fig. 1. Single-phase fault at the 110 kV transformer bushings

The overcurrent protection determines the fault mode, forms signals of the power transformer tripping (*Trip I > A*, *Trip I > B* and *Trip I > C*). Overcurrent protection operating time is 11 ms. The presence of the currents in the healthy phases *B* and *C* is caused by short-circuit point contribution through a grounded transformer neutral.

During two-phase ground fault at the 110 kV transformer bushings (Fig. 2) CTs in the *A* and *B* phases operate in a saturation mode which leads to the second harmonic appearance (signals *SG_A* and *SG_B*) in the currents I_A and I_B. Current I_B is less distorted, the second harmonic component of the current I_B is around 15 % and the signal *SG_B* is unstable.

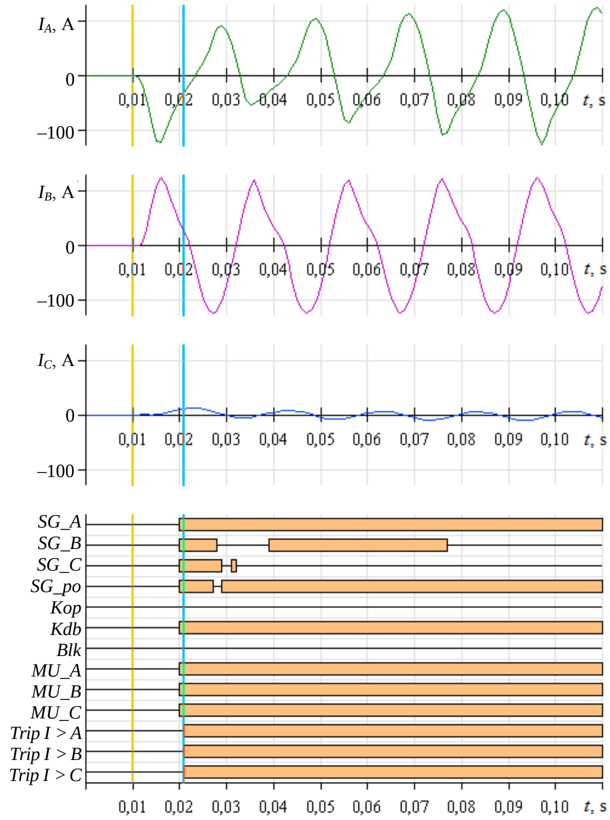

Fig. 2. Two-phase ground fault at the 110 kV transformer bushings

The signal of the blocking criterion *SG_po* is generated 10 ms after the beginning of the fault. Signal *SG_po* interrupts for a few milliseconds but during the most part of the fault process the signal *SG_po* is equal to the logical «one» which could result to overcurrent protection blocking. A high level of the fault current determines the appearance of the signal *Kdb* which forbids the blocking signal *Blk* formation.

The overcurrent protection determines the fault mode, forms signals of the power transformer tripping (*Trip I > A*, *Trip I > B* and *Trip I > C*). Overcurrent protection operating time is 11 ms. The presence of the current in the healthy phase *C* is caused by short-circuit point contribution through the grounded transformer neutral.

During three-phase fault at the 110 kV transformer bushings (Fig. 3) CTs in the *A* and *C* phases operate in a saturation mode which leads to the second harmonic appearance (signals *SG_A* and *SG_C*) in the currents I_A and I_C. The signal of the blocking criterion *SG_po* is generated 10 ms after the beginning of the fault. The current $I_{1h\text{-}neg}$ is close to zero and the signal *Kop* must be in logical «one» status in three-phase fault mode with sinusoidal phase currents. But the distortions of the currents of the phases *A* and *C* cause unstable signal *Kop* status. However the appearance of the blocking signal *Blk* is prohibited by signal *Kdb*. The overcurrent protection determines the fault mode, forms signals of the power transformer tripping (*Trip I > A*, *Trip I > B* and *Trip I > C*). Overcurrent protection operating time is 11 ms.

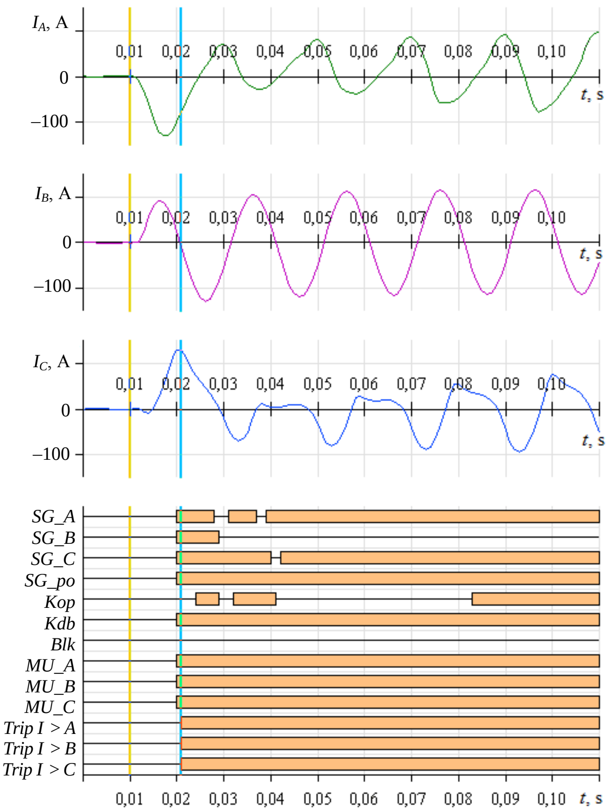

Fig. 3. Three-phase fault at the 110 kV transformer bushings

Phase currents have sinusoidal forms during two-phase fault at the 10 kV transformer bushings (Fig. 4). The signals *SG_A*, *SG_B*, *SG_C* and *SG_po* occur at the initial period of the fault that is caused by digital filter characteristic [3]. The digital filter uses a 20 ms window for the calculations which includes at the initial period both the pre-fault and fault modes. The blocking signal *Blk* is reset when the signal *SG_po* goes into logical «zero» status, the overcurrent stage generates signals to trip the power transformer (*Trip I > A*, *Trip I > B* and *Trip I > C*). Overcurrent protection operating time is 18 ms.

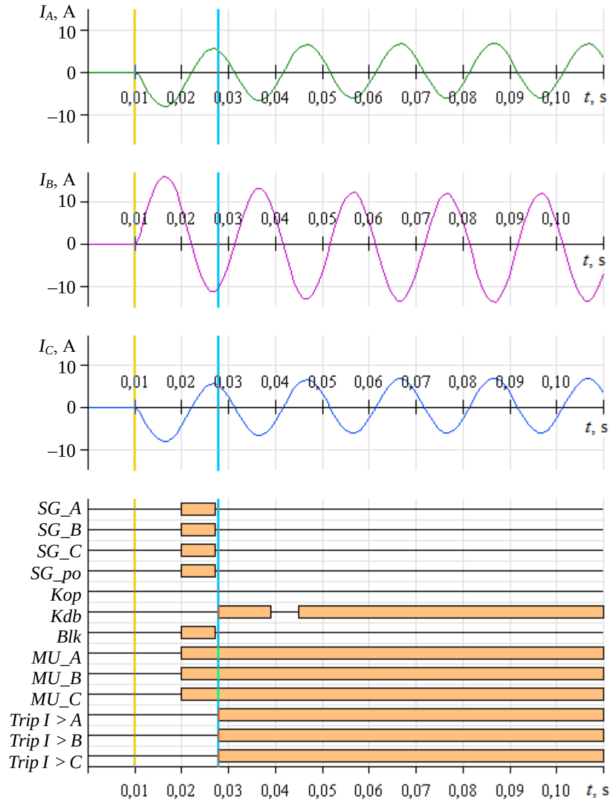

Fig. 4. Two-phase fault at the 10 kV transformer bushings

Phase currents have sinusoidal forms during three-phase fault at the 10 kV transformer bushings (Fig. 5). The current $I_{1h\text{-}neg}$ has a low value which is caused by the errors of the CTs, analog and digital filters. This means that the appearance of the signal *SG_po* is caused by low level of the signal $I_{1h\text{-}neg}$ but not caused by a high content of the second harmonic. This disadvantage of the $I_{2h\text{-}pos}/I_{1h\text{-}neg}$ criterion is eliminated by signal *Kop* generation. Additionally the high level of fault current determines the appearance of the signal *Kdb*. The blocking signal *Blk* is not formed and the overcurrent stage generates signals to trip the transformer (*Trip I > A*, *Trip I > B* and *Trip I > C*). Overcurrent protection operating time is 11 ms.

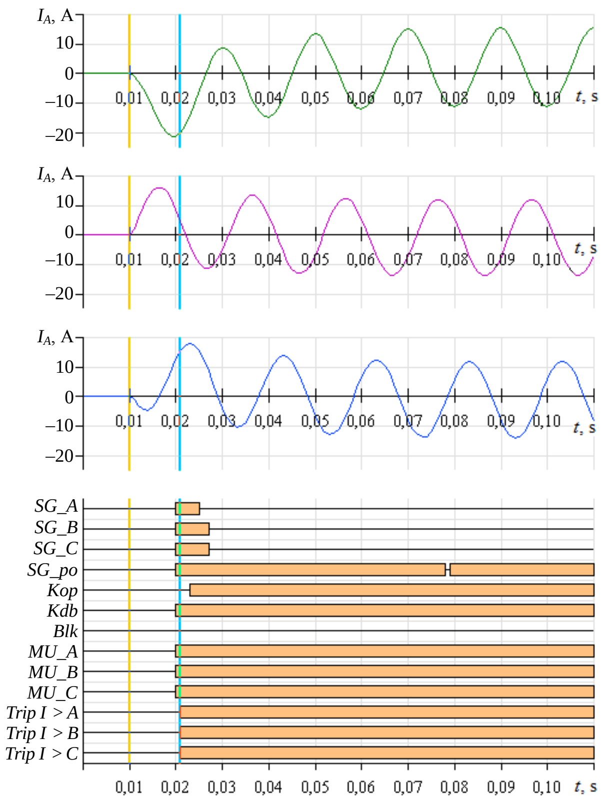

Fig. 5. Three-phase fault at the 10 kV transformer bushings

CONCLUSIONS

1. The analyzed blocking criterion does not retard transformer overcurrent protection tripping in fault modes. The proposed blocking algorithm provides necessary sensitivity to inrush current modes only and insensitivity to fault modes due to using the unlatch signal of the overcurrent protection (signal *Kdb*) and control of the content of the negative sequence current of the first harmonic (signal *Kop*).

2. The overcurrent stage with the proposed inrush blocking algorithm was realized in 1-millisecond cycle for the reason of a detailed study. Overcurrent protection operating time is 18 ms. Typically the protection functions into microprocessor devices are implemented in 10-millisekond cycle. Thus overcurrent protection operating time will increase to 28 ms.

3. The proposed inrush blocking algorithm can be implemented in the microprocessor current protection of transformers.

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