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АЛГОРИТМ БЛОКИРОВКИ ТОКОВЫХ ЗАЩИТ ПРИ БРОСКЕ ТОКА НАМАГНИЧИВАНИЯ

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BLOCKING ALGORITHM FOR CURRENT PROTECTION DURING INRUSH MAGNETIZATION CURRENT

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Представлен алгоритм блокировки токовых защит при броске тока намагничивания, реализуемый на основе оценки отношения тока прямой последовательности второй гармоники к току обратной последовательности первой гармоники.

Ключевые слова: бросок тока намагничивания, токовая защита.

Ил. 5. Библиогр.: 3 назв.

The paper presents blocking algorithm for current protection during inrush process. The algorithm is based on the evaluation of the ratio of the positive sequence second harmonic current to the negative sequence first harmonic current.

Keywords: inrush current, current protection.

Fig. 5. Ref.: 3 titles.

An important task for transformer current protection development is ensuring protection blocking at the inrush of magnetization current (IMC). IMC occurs at switching on of a no-load transformer, in cycles of automatic reclosing and automatic load transfer, at voltage recovery after external fault clearing. IMC can reach tenfold value in relation to rated current of transformer [1]. In all phases IMC is various in value, harmonious structure, form and decays rather slowly. Under the IMC influence all stages of current protections can operate falsely. The probability of false operations increases with increasing of sensitivity and operating speed of the protection stage.

IMC is an asymmetrical mode. As a rule, in two phases currents have unipolar character, as well maximum in value and contain an aperiodic component, main frequency harmonic and the highest harmonics. The third phase current is less,

practically doesn't contain an aperiodic component and is characterized with the significant presence of the highest harmonics. During IMC process all phase currents contain the first and second harmonics irrespectively of conditions of IMC emergence.

In symmetrical three-phase systems the first harmonics with the frequency $f = 50$ Hz in phase currents i_A, i_B, i_C form positive sequence system [1]:

$$\begin{cases} \underline{I_{A1h}} = I_{M1h}e^{j\cdot 0}; \\ \underline{I_{B1h}} = I_{M1h}e^{-j\frac{2\pi}{3}}; \\ \underline{I_{C1h}} = I_{M1h}e^{j\frac{2\pi}{3}}, \end{cases}$$

and second harmonics with frequency $2f = 2 \cdot 50 = 100$ Hz – negative sequence system:

$$\begin{cases} \underline{I_{A2h}} = I_{M2h}e^{j2\cdot 0} = I_{M2h}; \\ \underline{I_{B2h}} = I_{M2h}e^{-j\frac{2\cdot 2\pi}{3}} = I_{M2h}e^{j\frac{2\pi}{3}}; \\ \underline{I_{C2h}} = I_{M2h}e^{j\frac{2\cdot 2\pi}{3}} = I_{M2h}e^{-j\frac{2\pi}{3}}, \end{cases}$$

where $\underline{I_{A1h}}$, $\underline{I_{B1h}}$, $\underline{I_{C1h}}$ – vectors of first harmonic currents of phases A, B, C correspondingly; $\underline{I_{A2h}}$; $\underline{I_{B2h}}$, $\underline{I_{C2h}}$ – vectors of second harmonic currents of phases A, B, C correspondingly; I_{M1h}, I_{M2h} – amplitudes of first and second harmonics currents correspondingly.

In asymmetrical fault and asymmetrical loading modes current components of the positive and the negative sequences occur with the frequency of 50 Hz generally.

In IMC modes the first harmonic of phase currents includes a component of the negative sequence I_{1h-neg} considerably, the second harmonic of phase currents includes a component of the positive sequence I_{2h-pos} considerably. On the basis of the evaluation of the ratio I_{2h-pos}/I_{1h-neg} the blocking unit from IMC for the three phases current protection is constructed (Fig. 1).

The blocking unit includes the frequency filter 1 of the first current harmonic, the frequency filter 2 of the second current harmonic, filters 3 and 5 of the positive sequence current, the filter 4 of the negative sequence current, the element 6, which forbids current protection blocking, the element 7 of the negative sequence current occurrence control, the element 8 of calculation and control of blocking parameter at IMC, the element 9 logical "And", the element 10 "Ban".

The filter 1 allocates 50 Hz components i_{A1h}, i_{B1h}, i_{C1h} from phase currents i_A, i_B, i_C and the filter 2 allocates 100 Hz components i_{A2h}, i_{B2h}, i_{C2h}. The filter 3 forms positive sequence current I_{1h-pos} of the first harmonic and the filter 4 – negative sequence current I_{1h-neg} of the first harmonic. The filter 5 forms positive sequence current I_{2h-pos} on the basis of the second harmonic currents i_{A2h}, i_{B2h}, i_{C2h}. The element 6 compares current value I_{1h-pos} with setting $I_{blk.max}$. The element 7 counts I_{1h-neg}/I_{1h-pos} ratio and then compares it with setting K_{neg}. The element 8 counts I_{2h-pos}/I_{1h-neg} ratio and then compares it with setting K_{blk}. The element 9 allows blocking of the current protections when negative sequence of the first harmonic current has high level. The element 9 forms an output signal at simultaneous performance of conditions on the element 7 and the element 8. The element 10 forbids blocking of current protections by the signal created in the element 6.
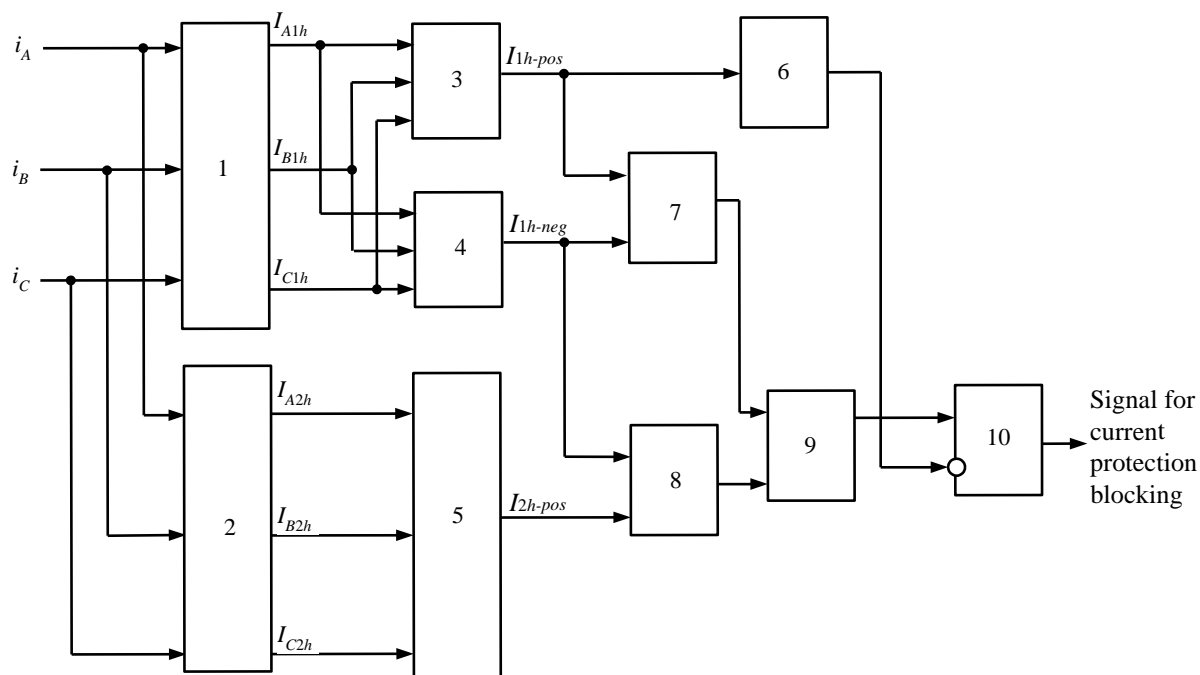

Fig. 1. The logical scheme of blocking unit from IMC for current protection

Signals at the outlets of filters 2 and 5 have a low level caused by an error of measurements in normal and overload modes, during self-start of engines and symmetric faults not being accompanied with current transformers (CT) saturation. Signals at the filter 1 outlets are proportional to phase currents and $I_{1h\text{-}neg}$ current at the filter 4 outlet is close to zero. Thus $I_{2h\text{-}pos}/I_{1h\text{-}neg}$ value can exceed value K_{blk} that lead to signal formation at the element 8 outlet. In considered symmetric modes the positive sequence current of the first harmonic $I_{1h\text{-}pos}$ has a significant value and the negative sequence current of the first harmonic $I_{1h\text{-}neg}$ has low value, thus $I_{1h\text{-}neg}/I_{1h\text{-}pos}$ relation less than the coefficient K_{neg} and the signal at the element 7 outlet isn't formed then the element 9 "And" doesn't allow blocking of the current protection.

Signals at the filters 2 and 5 outlets have low level caused by an error of measurements, signals at the filter 1 outlets are proportional to phase currents, the signal at the filter 4 outlet has significant value during asymmetrical faults not being accompanied with CT saturation. Thus $I_{2h\text{-}pos}/I_{1h\text{-}neg}$ value doesn't exceed value K_{blk} and the signal for the current protection blocking isn't formed.

The frequency filter 2 allocates 100 Hz current components, at the filter 5 outlet there is the positive sequence current of the second harmonic $I_{2h\text{-}pos}$ during symmetric and asymmetrical faults which are accompanied with CT saturation. At deep CT saturation $I_{2h\text{-}pos}/I_{1h\text{-}neg}$ value can exceed value K_{blk} that lead to signal formation at the element 8 outlet. CT saturation is caused by high fault's currents, thus value of current $I_{1h\text{-}pos}$ exceeds setting $I_{blk.\max}$ and the element 6 forms the signal which forbids signal formation for current protection blocking.

Significant values of second harmonic appear in currents i_A, i_B, i_C in modes which being accompanied with inrush magnetization current. Signals which are proportional to the first harmonic in currents i_A, i_B, i_C appear at the filter 1 outlets. First harmonic current components of the positive and the negative sequences appear at the filters 3 and 4 outlets respectively. $I_{1h\text{-}neg}/I_{1h\text{-}pos}$ ratio is more than the coefficient K_{neg} and the signal which allows current protection blocking is formed at the element 7 outlet. Signals which is proportional to the second harmonic in currents i_A, i_B, i_C appear at the filters 2 and 5 outlets. The numerical value of the blocking parameter $I_{2h\text{-}pos}/I_{1h\text{-}neg}$ exceeds setting K_{blk} and signal occurs at the element 8 inlet. Current $I_{1h\text{-}pos}$ can reach value equal to several rated currents of power transformer but doesn't exceed $I_{blk.\max}$ setting and the element 6 doesn't form a signal at the outlet. Existence of signals at the element 9 "And" inlets leads to forming the signal at the element 10 first inlet. As the signal at the element 10 second inlet is absent so the element 10 forms the signal for the current protection blocking.

Parameters of the offered criterion were calculated on the data basis obtained by the experience of switching on of the no-load transformer 110/10 kV with power 6.3 MV·A. Oscillograms of the IMC process are presented in Fig. 2–4. IMC in a phase A has periodic character, in phases B and C – aperiodic character.

In Fig. 5 values of the offered criterion and a classical restraining method from IMC [2] which based on the presence of the second harmonic in phase currents are shown. The frequency filters 1 and 2 are implemented on the basis of Goertzel's digital algorithm [3]. The offered criterion for IMC determination on the basis of the evaluation of the $I_{2h\text{-}pos}/I_{1h\text{-}neg}$ ratio provides the current protection blocking in three phases and has higher sensitivity to IMC compared to blocking which based on presence of the second harmonic into the phase currents (Fig. 5).
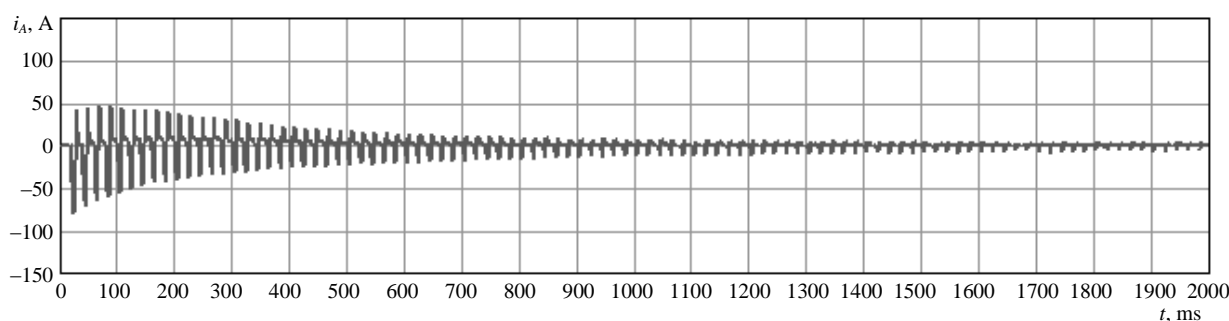

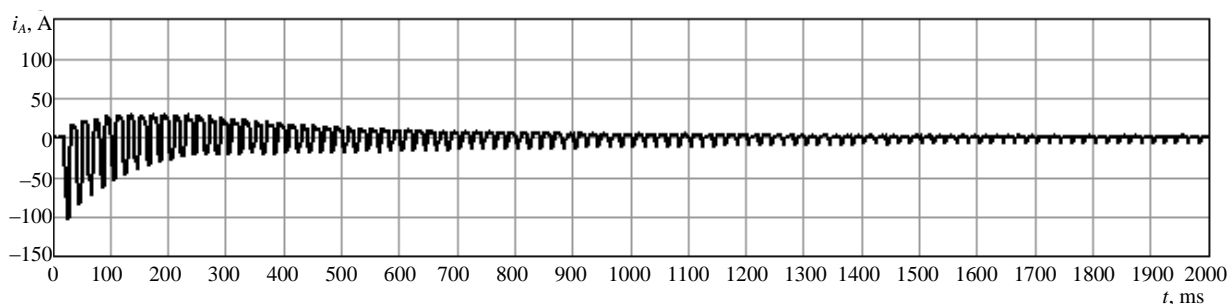*Fig. 2*. IMC in phase *A* after switching on of no-load transformer 6.3 MV·A

Fig. 3. IMC in phase *B* after switching on of no-load transformer 6.3 MV·A
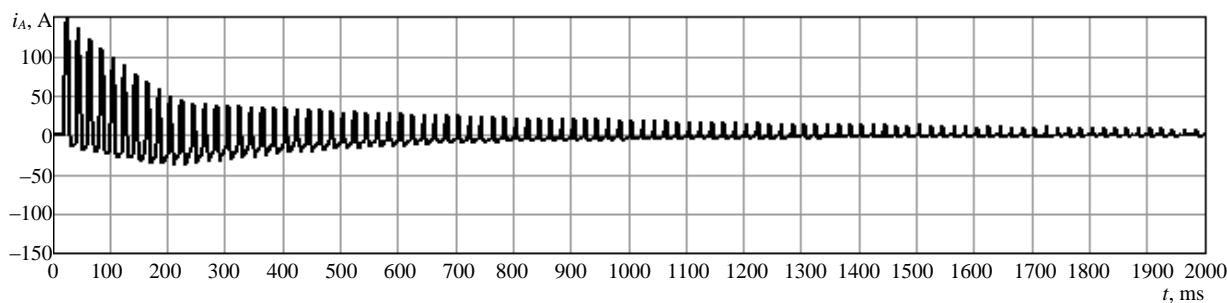

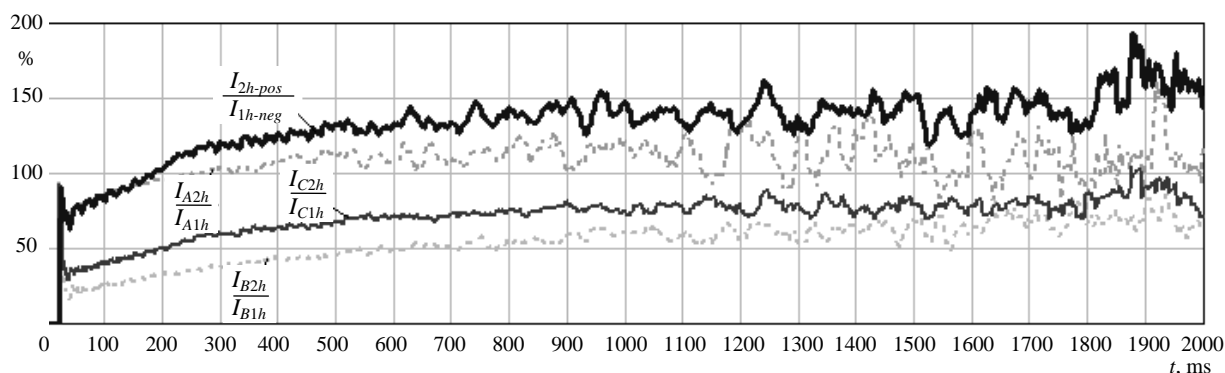*Fig. 4.* IMC in phase *C* after switching on of no-load transformer 6.3 MV·A

Fig. 5. Values of blocking parameters at IMC mode

CONCLUSIONS

The paper presents blocking algorithm for current protection during inrush process. The algorithm is based on the evaluation of the ratio of the positive sequence second harmonic current to the negative sequence first harmonic current.

The offered algorithm provides higher reliability due to simultaneous blocking of three phases of the current protection and also higher sensitivity due to use of the positive sequence current of the second harmonic in comparison with classical blocking which based on presence of the second harmonic into the phase currents and executed separately for three phases.

The offered algorithm needs to be tested in wide range of the IMC modes and at symmetric and asymmetrical faults including faults accompanied with CT saturation.

REFERENCES

1. **Evdokimov, F. E**. (1971) *Theoretical Bases Electricians.* Moscow: Vysshaya Shkola, 437–439.
2. **Kashtenni, B.,** & **Sevov, L.** (2009) Advanced Algorithm of Tuning From Magnetization Current Inrush. *Releishchik [Releyshchik],* 1, 31–41.
3. **Romaniuk, F. A.,** & **Loman, M. S.** (2012) Formation of Orthogonal Component Controlled Values in Microprocessor Protection Reducing Transformer. *Izvestiia Vysshikh Uchebnykh Zavedenii i Energeticheskikh Ob'edinenii – Energetika [Proceedings of the Higher Education Institutions and Power Engineering Associations – Power Engineering],* 4, 5–9.

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