

## SIMPLE VERY HIGH-SPEED OVERCURRENT PROTECTION RELAY

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*Приведено опис і представлення результатів експериментальних досліджень швидкодіючого гібридного реле струму з чутливим органом на герконі. Показано, що такі реле може бути з успіхом застосовано для прискорення дії основного релейного захисту.*

*Приведено описание и представлены результаты экспериментальных исследований быстродействующего гибридного реле тока с чувствительным органом на герконе. Показано, что такое реле может быть с успехом использовано для ускорения действия основной релейной защиты.*

Overcurrent and overload protection functions for both low-voltage and high-voltage consumers of electric power (and also electric networks) are usually realized on current relays with dependent or independent time delay characteristics, or on high-speed differential relays or impedance (distance) relays (for power line protection). In some situations, however (at close short circuits and high-power sources), the multiplex overcurrent passing through the protected object is capable of causing destruction of the object, even when it is protected with one of the above-mentioned protection relays. For such cases special very high-speed relays are stipulated. Usually the time delay of such high-speed relays, both electromechanical (for example, KO-1, produced by ABB) and microprocessor-based (for example, SEL-551C from Schweitzer Engineering Laboratories, BE1-50 from Basler Electric, RCS-931A/B from NARI, etc.) is within 20 to 40 milliseconds (as stated by manufacturers). In addition, electromechanical protection relays with instantaneous pick-up characteristics frequently provide even higher speeds (18-25  $\mu$ s), than microprocessor-based relays.

Promotional materials may sometimes be found which claim that an especially constructed high-speed microprocessor relay is capable of operating with a time delay of less than one period (less than 20  $\mu$ s), Fig. 1.

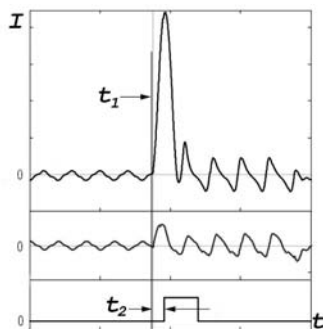


Fig. 1. Oscilloscope of operation of a high-speed microprocessor relay of the SEL-487B type. According to promotional materials its operation time is less than 20 milliseconds

Such small operating time delays really can be realized sometimes for microprocessor relays with injection of high current with an artificially fixed phase for the first half-cycle (as on the oscilloscope, Fig. 1). Unfortunately in practice such extreme artificially created

conditions are rarely achieved, therefore such unique operation times look more like an advertising gimmick than a parameter provided under real operating conditions.

Many companies are engaged in development and production of actual high-speed relays. The analysis of real transients of short circuits with high DC components and strong CT saturation has brought some researchers to the conclusion that it is impossible to provide relay protection for operating times of about one half-cycle (10 ms). These researchers offer a new algorithm based on measurement of first ( $di/dt$ ) and even second ( $d^2i/dt^2$ ) current derivatives. In reality, experimental oscillograms of transients (Fig. 2) confirm the stability of such parameters as a current derivative (speed of change of current, or in other words an inclination angle of the front of the first pulse of a current at short circuit) even with high DC components contained in the current. On the basis of these researches one of the Israeli companies has developed a microprocessor relay with this algorithm. Thus the relay has turned out to be relatively complex because measurement of only the second current derivative is insufficient for realizing necessary relay stability.

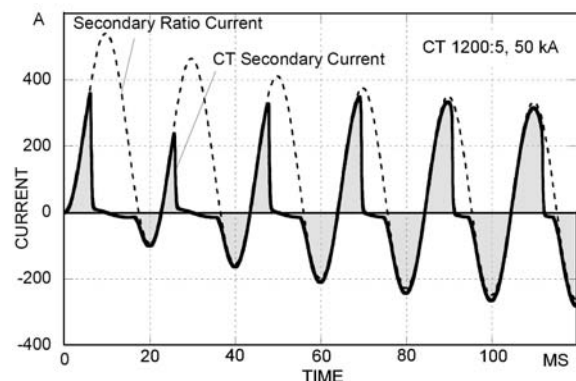


Fig. 2. Shows relation between the CT secondary current, applied to input of the relay and secondary ratio current at close short circuit mode

Inserting special elements for blocking of excessive relay operations is required because of the excessive sensitivity of the relay to some operating modes, as revealed. In addition, as the current derivative depends on a relation between an initial current before failure and a pickup current

at failure, it appeared that the relay does not always work properly if relative high load current is preceded to failure mode, and vice versa, excessive relay operations sometimes take place for great current changes (from zero value up to high values, but less of pickup value).

Despite some technical problems, preliminary tests of the relay prototype have confirmed its high speed. For the most difficult cases the time delay displayed was 8.4 ms, which it is much less than any microprocessor relays existing today in the market. The EMI compatibility and some other important relay parameters have not been investigated yet; nevertheless, the possibility of creation of the overcurrent microprocessor relay with an operation time of about a half period has been confirmed.

The author offers an alternative variant of a very simple and low-priced high-speed overcurrent relay with an algorithm based on measurement of instantaneous value of a current. The relay is so simple that it can be produced by the own staff of power systems. The offered overcurrent relay is based on a reed switch [1], with a high-voltage thyristor as an electronic amplifier, Fig. 3.

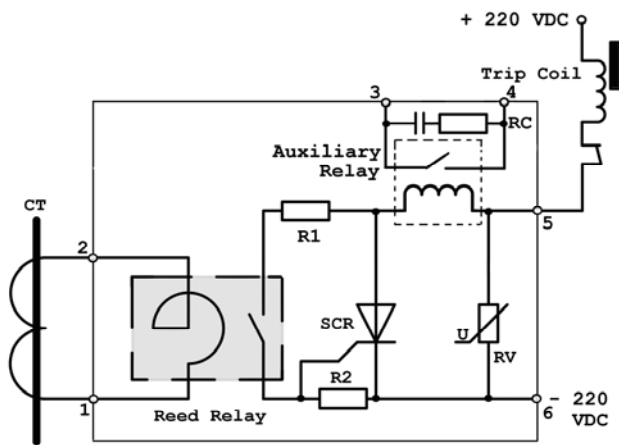


Fig. 3. Basic circuit diagram of a simple very high speed overcurrent relay on reed switch

The basic sensitive element in this device is the reed switch, which begins to vibrate at a pickup with frequency of 100 Hz. Its first pulse opens a powerful thyristor SCR, which energizes a circuit breaker trip-coil. The thyristor remains in the conductive condition, despite reed switch vibration, so long as the circuit is not turned-OFF by auxiliary contact of the circuit breaker. An addition auxiliary relay with a low impedance current coil and a spark protected power reed switch may be used for energizing of external electromechanical relays of automatic or signal systems. Subminiature high-voltage vacuum reed switches of the MARR-5 (Hamlin) or MIN-21 (Binsack Reedtechnik GmbH) types, with withstanding voltage of 1.5-2 kV and turn-ON times of not more than 0.6-0.7 ms, are used as metering elements that provide high reliability of the relay. A thyristor of the 30TPS16 type was also chosen with a large reserve for current (30A) and for voltage (1600 B), allowing to choose for protection from overvoltages the varistor RV, also having a large reserve (clamping voltage of about 800 VDC) regarding rated voltage (220VDC), providing both higher reliability and longer durability.

The reed switch module [2] can be provided with different methods of pickup adjustment: by means of a moving reed switch inside the coil, or by using different modules with different fixed values of pickup current. The last variant is quite acceptable, as this module is very simple and low-priced. After adjustment of the reed switch position in the coil, it must be fixed by means of silicon glue.

Output auxiliary relays are also made as reed relays (without adjustment) because their winding is not standard relay winding, but is designed as current winding (80–100 turnings) for current values suitable to the trip coil of circuit breakers. For such purpose power reed switches can be used, for example R14U, R15U (Yaskawa Electric America); MKA-52202 (Russia); GC 1513 (Comus Group); DRT-DTH (Hamlin), provided with spark protection (RC-circuit).

The prototype model of a 10A pickup reed switch module (Fig. 4) without a thyristor amplifier (thyristor switch-ON time is less than 10  $\mu$ s, which does not affect in any way the general time delay of the device) and without an auxiliary relay, has been submitted to tests.

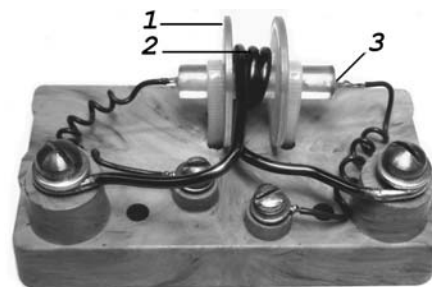


Fig. 4. Unit of reed switch, submitted on tests with rated pickup current of 10A

Tests were performed by artificial simulation of various modes on a current by means of a Power System Simulator F2253 (DOBLE Engineering), and also by injection in the module, by means of the same simulator, of real secondary currents of short circuit transients restored from COMTRADE files of the real failures in 160 kV power network, extracted from microprocessor-based transient recorders.

In the first series of experiences operation time of the module was measured at instant change of current on an input of the module in a range from 0.2–0.8  $I_{PICKUP}$  up to 1.2–5  $I_{PICKUP}$ , with various random phases of current transition and also with a zero phase of current sinusoid, Fig. 5. The tests verified that the lower limit predetermined current value preceded to pickup current does not affect operating time (Fig. 6), as against microprocessor based relay reactions to current derivatives.

Research also affects harmonics (contained in a current) on operating time at different phase transitions of a current, Fig. 7, and verified that even the high harmonics content does not affect operating time.

The main factors are still the phase and magnitude of a current transient. For the most difficult case, that is at small current  $I = 1.2I_{PICKUP}$  and with switching current phase at close to 45°, maximal operation time can reach 7–8 ms.

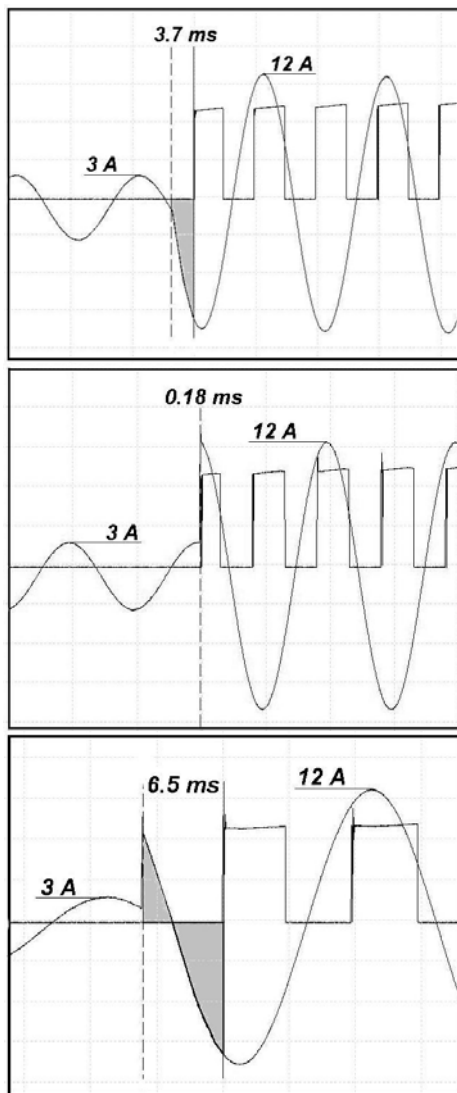


Fig. 5. Some oscillograms of operation of reed switch unit at instant change of current with various phases of current transition. Non-operating zones of the relay are marked

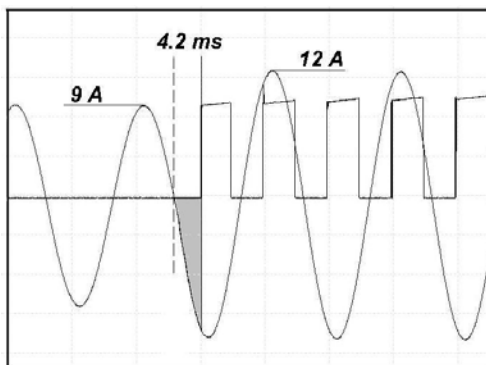


Fig. 6. Oscillogram of operation of relay with previous non-operating current (9 A), near to a pickup (10 A)

Heavier testing appeared for real secondary currents of short circuit transients contains a high DC component, causing displacement of a sinusoid of current concerning an axis, Fig. 8. The maximal operation time fixed at these tests reach 9.4 ms. In addition, in some experiences with high DC components, pickup current decreased by as much as 0.7 of the rated pickup current. This occurred when the relay pickup phase occurred at the moment

corresponding to the maximal displacement of the first half wave of a current sinusoid. For such conditions relay picked up at much smaller current than at a normal sinusoid in the continuous mode. In our opinion, this phenomenon is not so essential, as the basic purpose of such high-speed relays is not exact current measure, but only detection of the presence of a dangerous short circuit for acceleration of action of basic relay protection. In other words, at adjustment of the relay for a primary current, for example, 20  $\kappa$ A, it is possible to achieve pickup in some cases at a current of 14  $\kappa$ A that also specifies a dangerous short circuit, as well as pickup of a 20  $\kappa$ A current. Nevertheless, in some cases this phenomenon can limit application of reed relays.

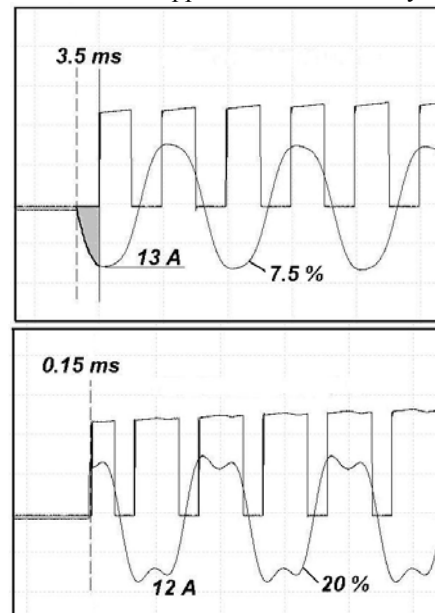


Fig. 7. Oscillograms of operation of relay at high harmonic content in current (for contents of the third harmonic of 7.5 % and 20 %)

Due to use of the reed switch as a sensitive threshold element, the high speed overcurrent relay developed is not only very simple, low-priced, and accessible to manufacturing even by technicians, but also high steady to external electromagnetic influences: to distortions of a current, to voltage spikes, to powerful high-frequency radiations [3], etc. Such sensitive elements on a reed switch, adjusted on operation at the high rate of a current, can be built-in also in various microprocessor protection relays (or can be connected to them outside, through a separate input) as the bypassed element of the microprocessor for accelerator tripping of the circuit breaker.

#### CONCLUSIONS

1. Development of a high-speed overcurrent relay with a time delay of up to 10 ms for acceleration of action of main protection is an actual problem.
2. The algorithm for the microprocessor-based overcurrent relay which provides real operating time within the one half-cycle of a current is now known.
3. Use of the reed switch as a sensitive component of high speed overcurrent relays is a prospective direction allowing creation of simple and at the same time, competitive relays, for the purpose of revealing close short circuits and acceleration of action of basic relay

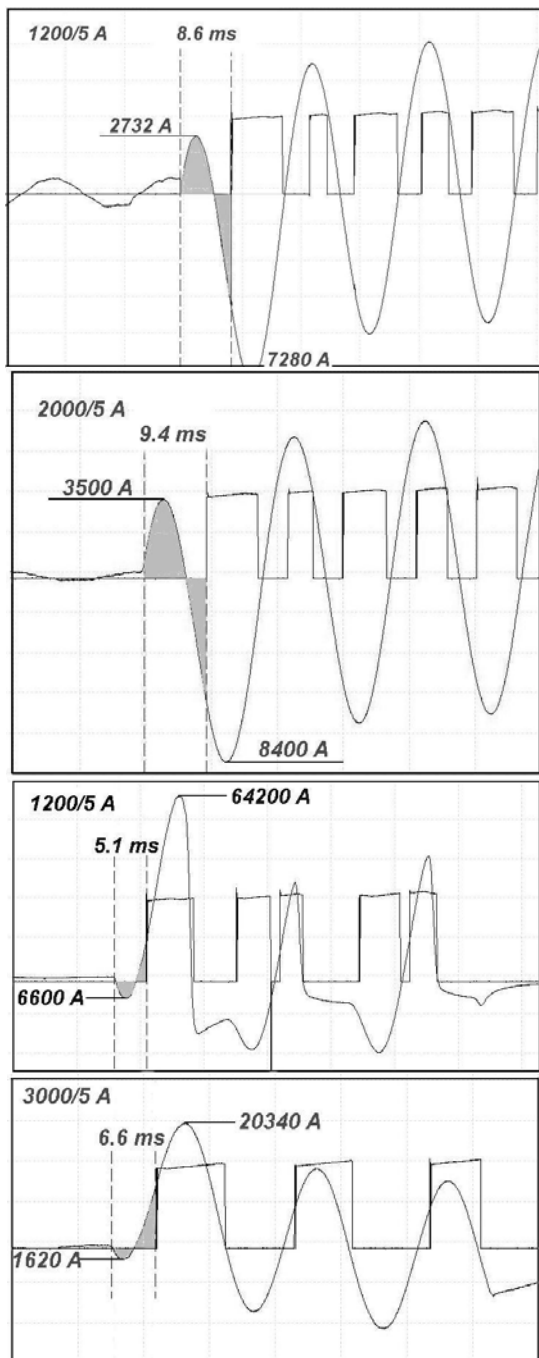


Fig. 8. Oscillogram of operation of the relay for actual short circuit transients containing a high DC component

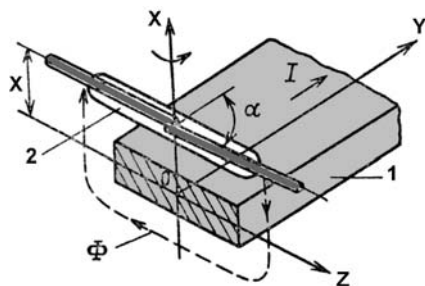


Fig. 9. Principle of winding-free overcurrent reed relay. 1 – current carrying bus bar; 2 – reed switch with pickup depends on distance X from the bus bar and on angle  $\alpha$  for longitudinal axis Y

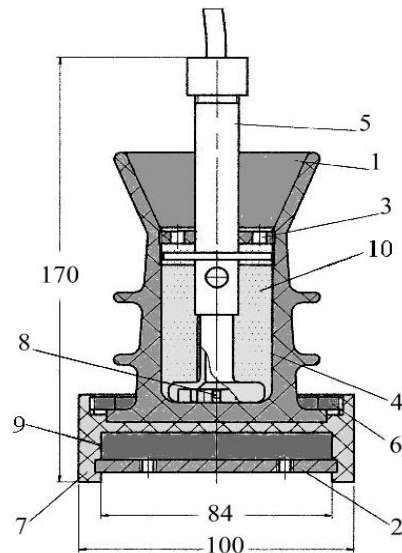


Fig. 10. Design of high-voltage overcurrent reed relay not requiring CT: 1 - main insulator; 2 - fixative plate; 3 - inside nut; 4 - semi-conductive cover; 5 - bushing; 6 - fixative nut; 7 - fastener; 8 - reed switch; 9 - high-voltage bus bar; 10 - epoxide compound



Fig. 11. External view of high-voltage (24 kV) overcurrent reed relay not requiring CT

#### REFERENCES

- [1] Gurevich V. Protection Devices and Systems for High-Voltage Applications. – Marcel Dekker, New-York, 2003, 304 pp.
- [2] Gurevich V. Electric Relays: Principles and Applications. – CRC Press (Taylor & Francis Group), Boca Raton-London-New York, 2005, 704 pp.
- [3] Gurevich V. Electromagnetic Terrorism: New Hazards. – Electrical Engineering & Electromechanics, 2005, No. 4, pp. 81-83.

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