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Modern Circuit Breaker Protection and Control

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1 INTRODUCTION

Modern microprocessor-based relay protection and automation devices (terminals) installed on high-voltage substations integrate a great number of functions that were previously performed by separate panels and devices. Such an approach makes it possible to improve relay protection and automation system performance and facilitates its maintenance. Among others, breaker protection and control functions are also implemented by means of intelligent electronic devices (IEDs).

Long-term operating experience with the intelligent electronic devices has resulted in typical application schemes for substations of various voltage levels. However, it has been revealed that conventional breaker protection and control schemes are far away from being perfect, for example, due to lack of control circuit reliability [1]. Besides, new requirements are set forth with regard to implementation of new service functions associated with equipment depreciation accounting.

Present report gives consideration to up-to-date solutions in the field of reliability enhancement and breaker control algorithms improvement, achieved with innovative technology and novel approach to devices interaction arrangement.

2 BREAKER PROTECTION AND CONTROL ARCHITECTURE

Depending on application, various designs are reasonable: the breaker protection and control function is implemented in a separate device (IED) or merged with bay protection (Fig. 1).

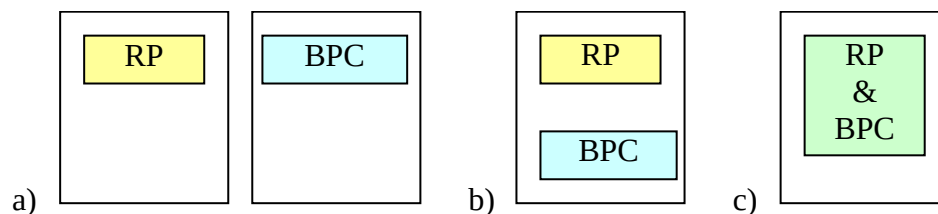


Fig. 1: Alternatives for breaker protection and control (BPC) and bay protection (RP) arrangement:
a – implementation in separate cubicles; b – implementation in separate terminals;
c – the functions are performed by single terminal

Functionality of breaker protection and control comprises the following modules:

- automatic reclosing (AR) for bays and buses with synchrocheck/phasing;
- manual breaker control;

- breaker opening initiated by protection;
- breaker failure protection (BFP function);
- breaker condition monitoring;
- breaker coils protection against continuous current;
- open phase protection and pole discrepancy protection for breakers with phase-segregated control.

Advanced breaker protection and control improves diagnostics of the breaker condition and the breaker control circuits:

- breaker tripping and mechanical capability estimation;
- breaker opening/closing cycle time diagnostics;
- breaker control circuit integrity monitoring.

2.1 Control circuit supervision

Control circuits are the most critical in relay protection. In a conventional solution, they are supervised by means of IED's binary inputs (Fig. 2). Binary input DI1 is designed for the coil voltage and is used to supervise coil circuit integrity; low-voltage binary input DI2 monitors current flow in the breaker coil when the latter is activated. It should be noted that resistor R2 is selected on the basis of binary input DI2 performance at the rated voltage range and coil's performance. It may be impossible to fully satisfy these conditions if the rated coil current is high.

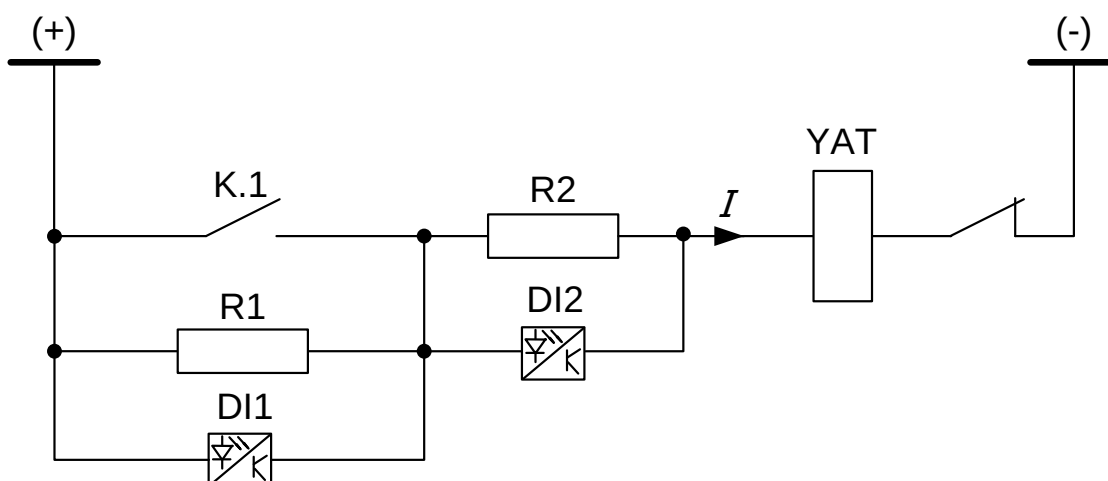


Fig. 2: Use of binary inputs for breaker coils circuit supervision

Field experience has revealed that due to switching and continuous overvoltages binary inputs can burn out. Due to special circuit design low-voltage inputs (DI2) are especially subjected to it. As a result, breaker protection and control device loses information about actual circuit condition. Moreover, there were several cases detected when a burn-out input DI1 caused short-circuit and unwanted coil operation. Another drawback of binary inputs lies in their little information content: they can only indicate whether there is a signal or there is no signal, with certain threshold. This doesn't allow for supervision of the circuit, e.g. faults in the coil (YAT).

These problems of binary inputs are solved by measuring corresponding currents and voltages in control circuits. As far as direct current is to be measured, no electromagnetic CTs or VTs can be used for this purpose. In modern devices [2], Hall-effect current and voltage sensors are applied. They ensure required characteristics with regard to control circuit design: sensors provide galvanic isolation of circuits, do not introduce additional resistance into the measurement circuit and they are highly resistant to overvoltages.

For one of the alternatives of the current sensor connection see Fig. 3. Voltage sensor MV supervises the coil circuit voltage level, while current sensor MA measures the coil current.

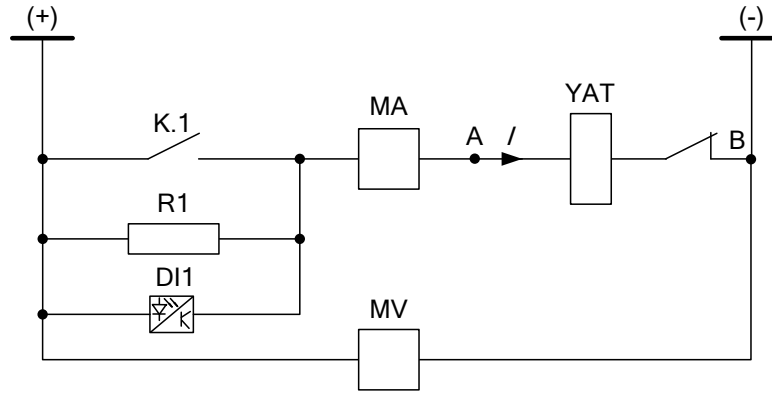


Fig. 3: Use of current and voltage sensors for supervision of coil control circuits

The advantage of such a scheme is that in this case it's possible to supervise not only circuit opening, but to perform other types of diagnostics:

- faults in a coil;
- inadmissible voltage drop in a coil circuit.

Coil faults (section AB in Fig. 3) can be manifested in short-circuit of its several turns and control circuit wires short-circuit resulting in breaker failure. Both faults cause decrease of supervised resistance. This can be identified by breaker protection and control device in an effective way.

Therefore, circuit diagnosis function supervises the following features:

- circuit effective resistance is within the nominal range;
- current level in the control circuit;
- rate of current rise in coil circuit;
- continuous voltage level monitoring;
- presence and value of current in a circuit after relay protection and automation devices issue command.

It should be noted that some of the parameters are supervised in a conventional scheme; however, measurement makes it possible to provide higher sensitivity to faults. For example, the coil-circuit breaker is initiated, when the coil current exceeds the set value. However, built-in instantaneous overcurrent protection (based on analog principle) has limited setup functionality and low accuracy characteristics. Moreover, due to lack of predicting function instantaneous overcurrent protection performs separation after the current goes up to the values that are critical for the circuit.

Typical current waveform in a coil circuit is shown in Fig. 4. There are two sections where the current rises. Interturn faults in a coil cause extension of a leading edge on a record. Current waveform in breaker protection and control device can be analyzed by various digital signal processing algorithms [3].

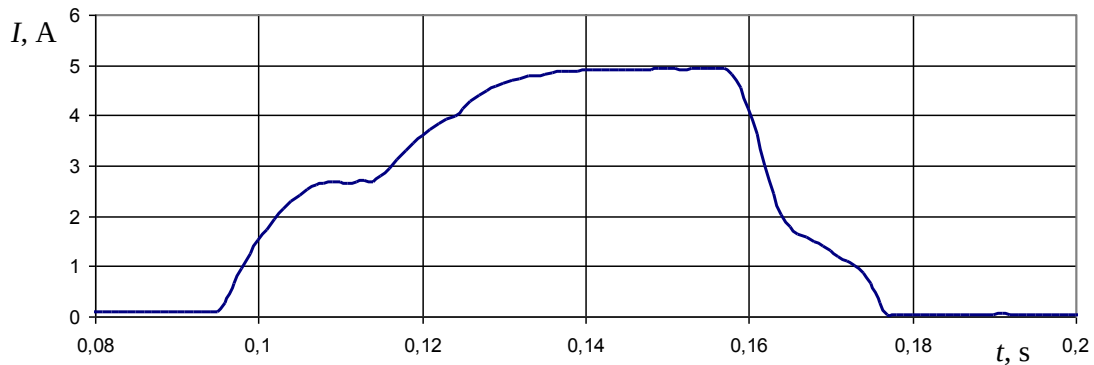


Fig. 4: Current waveform in a coil circuit

Current value taken as the operation state is gradually regulated in breaker protection and control device making it possible to simplify the dc circuits and to make a typical hardware to be able to control breakers with different rated currents of coils.

There is an alternative with coil circuit supervision (section AB in Fig. 3) by measuring its equivalent resistance in “no-current” mode in coil (when contact K.1 is not closed). In this case more stringent requirements are set forth to dc current and voltage sensor operation accuracy.

For breakers with phase-segregated coil control the current is supposed to be measured in each phase circuit, to be able to perform all types of diagnostics in full.

2.2 Blocking functions in breaker protection and control device

Modern breakers have built-in functions for their condition parameter monitoring: SF₆ or air pressure, auxiliary voltage, spring charging motor conditions, etc. All these indicators can be used for signaling as well as when decision about command issue to the breaker is made. Breaker protection and control devices usually implement typical schemes of command blocking and permit modification of the algorithm with the help of user configuration by setting up logical connections and appropriate delays (Fig. 5, a). However, this may be insufficient as breaker opening commands by-pass breaker protection and control device, in order to speed up the action (K1.1 in Fig. 5, b). In this case, it's more reasonable to use blocking scheme in protection and control device to prevent unwanted breaker operation (contact K3.1 in Fig. 5, b). Such a scheme makes it possible to block breaker operation depending on disconnector or earth-switch state as well.

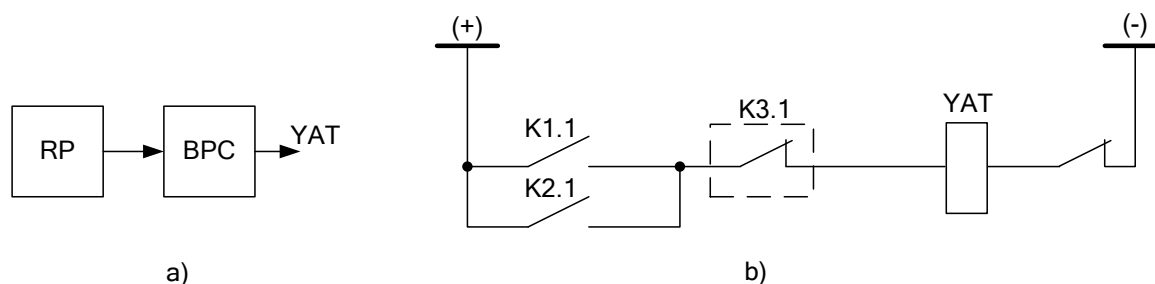


Fig. 5: Alternatives of breaker actuation

2.3 Breaker opening and closing cycle time diagnostics

During the exploitation a breaker wears and its parameters deviate from the rated ones. Particularly, this is observed in increase of breaker closing and opening commands execution. Breaker protection and control device is able to detect the problem, send warning signals to the personnel about exceeding the nominal duration or to block breaker control.

Operation duration is monitored by time difference between control command signal, breaker condition signals and phase currents.

2.4 Breaker tripping and mechanical capability estimation

Switching and mechanical capabilities for breakers are considered as reliability factors [4], [5]. Breaker protection and control device is able to monitor the breaker parameters:

- remanent mechanical capability is evaluated by the number of switching operations performed by the breaker;
- remanent switching capability additionally considers the value of breaking currents.

Remanent breaker capability is evaluated by long-time monitoring of breaker closing and opening cycles [6]. The initial breaker condition is introduced by the personnel into breaker protection and control device in the course of setup.

The mechanical capability is evaluated at each breaker opening. Closing and opening cycles are determined by change of breaker condition signals. False signal change at short-time auxiliary voltage decrease and various disturbances is eliminated by breaker opening commands (manual or automatic) supervision.

The remaining breaker tripping capability is calculated at the instant of breaker opening for each phase (pole) separately. The capability is decreased by the value defined by the dependence of allowed

breaker opening cycles on the switching current level $N=f(I_{Break.})$, for example, according to [5] (Fig. 6).

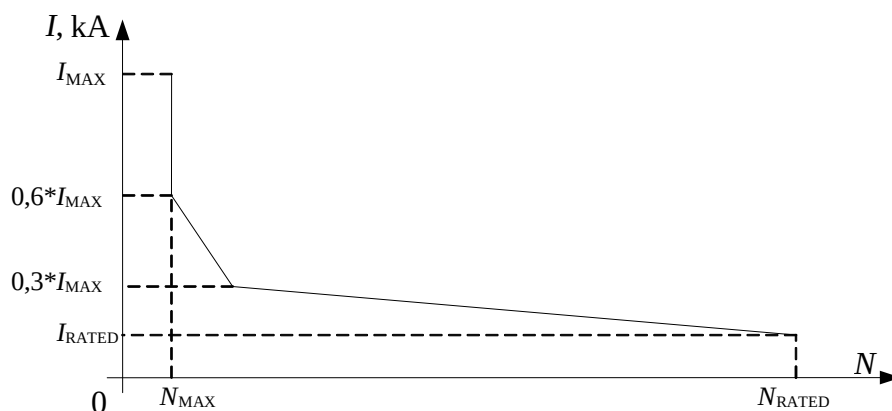


Fig. 6: Typical characteristic of breaker tripping capability

Breaker mechanical and tripping capabilities monitoring function performs signaling when residual life goes below the preset values. When remaining breaker capability reaches zero level, breaker closing can be blocked in order to prevent its damage.

3 CONCLUSION

Modern breaker protection and control devices are intellectual electronic devices, which are designed not only for execution of manual and automatic commands, but also for comprehensive diagnosis of switch gear. Among other issues, state-of-the art technology makes it possible to enhance control circuit reliability and to make more flexible blocking system at breaker process protection operation.

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