Full Selectivity of Automatic Breakers Cascading in 0.4 kV Networks

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Abstract

The article deals with the issue of determining the regularity of the selection of selective switches. To solve this problem, the object of research is single-module automatic breakers with different characteristics and numbers, which are installed on a DIN Rail. The results of the work allow us to make such a selection of automatic breakers that can ensure guaranteed disconnection of the automatic breaker of the head section when an overcurrent flows through one of the branches, as is also identify a damaged branch of the distribution network.

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1 Introduction

The solution of the design issues of the lighting system and power networks (EOM) of the apartment, as well as non-residential premises, includes aspects of the design of electrical equipment placed in the switchboard. In particular, the choice of automatic breakers (AB) (or the function for switching off overcurrent by differential breakers) at the head sections and at the branches is considered. If a short circuit occurs on one of the branches, it is necessary that the AB of the emergency branch is turned off, and not the head section, since this will lead to the shutdown of the entire distribution network. If the AB is switched off in the head section, it will be difficult to determine which

branch the short circuit occurred on. Therefore, the selection of automatic breakers, taking into account the selectivity factor, allows us to:

- ensure the guaranteed failure of the head section automatic breaker when an overcurrent flows through one of the branches;

- identify the damaged branch of the distribution network.

2 Literature Review

The object of research is automatic breakers (single-module, DIN-Rail mounted) (Figure 1a, 1b) [1, 2]. The initial data of the study is the technical data on the switches, including their characteristics and nominal values.

The subject of the study is the regularities of the selection of selective switches.
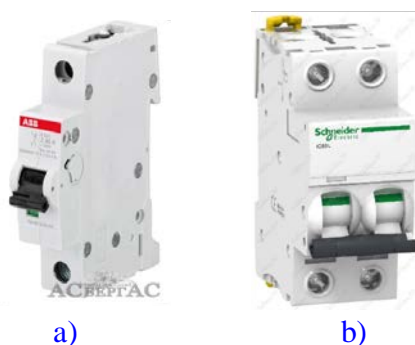
a)   b)
Figure 1: Automatic breakers.
A –a single-module AB with a response characteristic of Z [1];
B-a two-module AB with characteristic L [2].

According to sources [3-9], the characteristics of automatic breakers A, B, C, D, Z, L, K have the following limits of the ranges of operation of both thermal and electromagnetic decouplers (Table 1).

Table 1: Values of the multiplicity of actuation currents of electromagnetic and thermal disconnectors

Electromagnetic			Thermal (1 hour of operation)		
Lower limit	Characteristics	Upper limit	Lower limit	Characteristics	Upper limit
$2I_{nom}$	A [6,7, 8]	$3I_{nom}$	$1,3I_{nom}$	A [7]	-
$3I_{nom}$	B [3, 4, 5]	$5I_{nom}$	$1,13I_{nom}$	B [3, 4, 5]	$1,45I_{nom}$
$5I_{nom}$	C [3, 4, 5]	$10I_{nom}$	$1,13I_{nom}$	C [3, 4, 5]	$1,45I_{nom}$
$10I_{nom}$	D [3, 4, 5]	$20I_{nom}$	$1,13I_{nom}$	D [3, 4, 5]	$1,45I_{nom}$
$3I_{nom}$	Z [4, 5]	$5I_{nom}$	$1,05I_{nom}$	Z [4, 5]	$1,2I_{nom}$
$5I_{nom}$	L [6]	$10I_{nom}$	$1,05I_{nom}$	L [6]	$1,2I_{nom}$
$10I_{nom}$	K [4, 5]	$14I_{nom}$	$1,05I_{nom}$	K [4, 5]	$1,2I_{nom}$

Another parameter to be considered in this study is the value of the rated current. A number of rated currents are normalized according to the current standard GOST R 50345-2010 [3]: 6, 8, 10, 13, 16, 20, 25, 32, 40, 50, 63, 80, 100, 125 A.

In practice, a number of these values are actually used. For example, there are automatic breakers with nominal values available on the market [10]: 6,8, 10, 13, 16, 20, 25, 32, 40, 50, 63, 80, 100, 125 A. Thus, all the values of the current series are the same, which means that the AB manufacturers do not deviate from the standard [3] when choosing the values of the rated current of automatic breakers.

3 Method

The concept of "full selectivity" of automatic breakers is associated with the unambiguous understanding that one and only one AB will work at a given current value at a certain time.

As a rule, the sequence of operation of series-connected automatic breakers (fig. 2) is as follows:

- QF31 is triggered first;
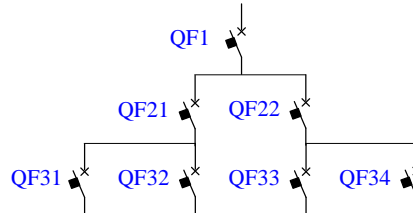
- then QF21 is triggered;

- QF1 is triggered last.

Figure 2: Automatic breakers connection diagram

Fully selective Automatic breakers are considered to be those whose time-current characteristics (VTC) do not overlap. If the VTC of the lower-level device is higher than the VTC of the head unit, then the sequence of operation will be reversed, which will lead to the disconnection of the entire network and all consumers at once.

The selectivity calculation is necessary for a situation where there are AVS of different ratings and/or different characteristics in the automatic. Based on the results of the calculations, you can determine whether there will be an intersection of the VTH devices or not. That is, we can clearly and unambiguously identify the time intervals during which the sequentially activated automata will work, and say in what order.

However, in addition to the concept of full selectivity (when the VTC devices do not intersect), there is the concept of partial selectivity (VTC intersect and the concept of coordination current is introduced). Also, selectivity can be provided by changing the "current" or "time". Based on the sources [3, 10, 11], Table 2 is compiled with the types of selectivity.

Table 2: Types protection selectivity

Selectivity type	Implementation on the time-current characteristic	Selectivity type	Implementation on the time-current characteristic
Current selectivity		Full selectivity	
Temporal selectivity		Partial selectivity	

Table 2 allows you to understand in which case, namely, at what level of power supply, it is advisable to apply a particular type of selectivity. In addition, the types of selectivity (current or time) require design implementations in the device of the protective device, which affects its cost.

At the same time, it is necessary to distinguish between the concepts of "protection coordination" and "selectivity", since these concepts are not synonymous [11] (Fig. 3).
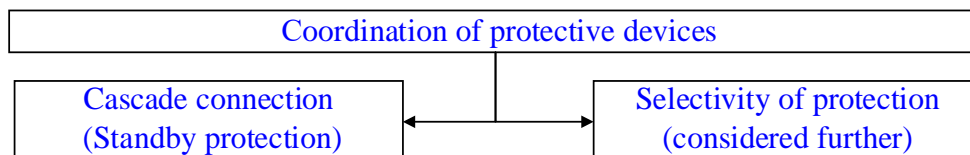

Figure 3: Structuring the concept of "coordination of protective devices".

To ensure current selectivity, it is necessary to select automatic switches of different ratings and / or characteristics. There is no time selectivity in the case of modular automatic breakers, in which the shutdown time is normalized and not regulated (it is not possible structurally). Therefore, we can not "move" the characteristics of automatic breakers up (along the time axis), but we can "move" the VTC AB only along the current axis, and discretely (that is, separate current values, normalized by GOST), selecting the automatic breaker according to Table 4. Taking into account all the above, we get selectivity, called full and current [12-15].

At the power supply level of 0.4 kV, namely, for consumers with increased requirements for the reliability of their power supply, the primary issue is the correct coordination of protections and the unambiguous distribution of the time-current characteristics of the devices. That is, it is necessary that the condition of "full selectivity" is strictly fulfilled.

4 Result and Discussion

Let's consider an example of choosing modular automatic breakers installed on a DIN rail according to the condition of full selectivity. Let us say we have an electrical circuit as in Figure 4.
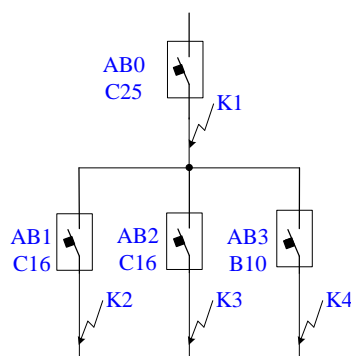
Figure 4: The scheme in question

1. Check the selectivity of AB0 and AB1 (At the short circuit at the point K2, K3). 1. It is necessary to determine the response intervals:

$$I_{AB1\_Low} \leq I_{AB1} \leq I_{AB1\_High}, \qquad I_{AB0\_Low} \leq I_{AB0} \leq I_{AB0\_High},$$

$$5 \times I_{nom} \leq I_{AB1\_(C)} \leq 10 \times I_{nom}, \qquad 5 \times I_{nom} \leq I_{AB0\_(C)} \leq 10 \times I_{nom},$$

$$5 \times 16 \leq I_{C16} \leq 10 \times 16, A, \qquad 5 \times 25 \leq I_{C25} \leq 10 \times 25, A,$$

$$80 \leq I_{C16} \leq 160, A. \qquad 125 \leq I_{C25} \leq 250, A.$$

2. It is necessary to determine the presence/absence of intersections of the AB response intervals:

$$I_{AB1\_High} < I_{AB0\_Low},$$

$$160 < 125, A - condition\ is\ not\ met.$$

1. Check the selectivity of AB0 and AB4 (At the short circuit at point K4). 1. It is necessary to determine the response intervals.

$$I_{AB3\_Low} \leq I_{AB3} \leq I_{AB3\_High}, \qquad I_{AB0\_Low} \leq I_{AB0} \leq I_{AB0\_High},$$

$$3 \times I_{nom} \leq I_{AB3\_(C)} \leq 5 \times I_{nom}, \qquad 5 \times I_{HOM} \leq I_{AB0\_(C)} \leq 10 \times I_{HOM},$$

$$3 \times 10 \leq I_{B10} \leq 5 \times 10, A, \qquad 5 \times 25 \leq I_{C25} \leq 10 \times 25, A,$$

$$30 \leq I_{B10} \leq 50, A. \qquad 125 \leq I_{C25} \leq 250, A.$$

2. It is necessary to determine the presence/absence of intersections of the AB response intervals

$$I_{AB3\_High} < I_{AB0\_Low},$$

$$50 < 125, A - condition\ is\ met.$$

Based on the fulfillment/non-fulfillment of the inequalities, it can be concluded that the automatic automatic breakers on the branches are selectively triggered (Table 3).

Table 3: Results of checking the scheme under the condition of "full selectivity"

Name of the AB	Characteristic and nominal value	Higher-level AB	Characteristic and nominal value	Selectivity condition
AB1	C16	AB0	C25	not executed
AB2	C16	AB0	C25	not executed
AB3	B10	AB0	C25	in progress

As a result of the work done, a table was compiled, on the basis of which it is possible to select the automatic switch according to the condition of complete selectivity (Table 4).

Table 4: Selection of the automatic breaker according to the condition of full selectivity

Lower-level AB: **C** — Higher-level AB: **C**

Possible AB (lower)	16	20	25	32	40	50	63	80	100
6	+	+	+	+	+	+	+	+	+
8	-	+	+	+	+	+	+	+	+
10	-	-	+	+	+	+	+	+	+
13	-	-	-	+	+	+	+	+	+
16	-	-	-	-	+	+	+	+	+
20	-	-	-	-	-	+	+	+	+
25	-	-	-	-	-	-	+	+	+
32	-	-	-	-	-	-	-	+	+
40	-	-	-	-	-	-	-	-	+
50	-	-	-	-	-	-	-	-	-

Lower-level AB: **D** — Higher-level AB: **D**

Possible AB (lower)	16	20	25	32	40	50	63	80	100
6	+	+	+	+	+	+	+	+	+
8	-	+	+	+	+	+	+	+	+
10	-	-	+	+	+	+	+	+	+
13	-	-	-	+	+	+	+	+	+
16	-	-	-	-	+	+	+	+	+
20	-	-	-	-	-	+	+	+	+
25	-	-	-	-	-	-	+	+	+
32	-	-	-	-	-	-	-	+	+
40	-	-	-	-	-	-	-	-	+
50	-	-	-	-	-	-	-	-	-

Lower-level AB: **B (Z)** — Higher-level AB: **C**

Possible AB (lower)	16	20	25	32	40	50	63	80	100
10	+	+	+	+	+	+	+	+	+
16	-	+	+	+	+	+	+	+	+
20	-	-	+	+	+	+	+	+	+
25	-	-	-	+	+	+	+	+	+
32	-	-	-	-	+	+	+	+	+
40	-	-	-	-	-	+	+	+	+
50	-	-	-	-	-	-	+	+	+
63	-	-	-	-	-	-	-	+	+
80	-	-	-	-	-	-	-	-	+
100	-	-	-	-	-	-	-	-	-

Lower-level AB: **B** — Higher-level AB: **D**

Possible AB (lower)	16	20	25	32	40	50	63	80	100
25	+	+	+	+	+	+	+	+	+
32	-	+	+	+	+	+	+	+	+
40	-	-	+	+	+	+	+	+	+
50	-	-	-	+	+	+	+	+	+
63	-	-	-	+	+	+	+	+	+
80	-	-	-	-	-	+	+	+	+
100	-	-	-	-	-	-	+	+	+
125	-	-	-	-	-	-	+	+	+

Lower-level AB: **D** — Higher-level AB: **C**

Possible AB (lower)	16	20	25	32	40	50	63	80	100
3	+	+	+	+	+	+	+	+	+
4	-	+	+	+	+	+	+	+	+
6	-	-	+	+	+	+	+	+	+
8	-	-	-	-	+	+	+	+	+
10	-	-	-	-	-	+	+	+	+
13	-	-	-	-	-	-	+	+	+
16	-	-	-	-	-	-	-	+	+
20	-	-	-	-	-	-	-	-	+

Lower-level AB: **K** — Higher-level AB: **C**

Possible AB (lower)	16	20	25	32	40	50	63	80	100
4	+	+	+	+	+	+	+	+	+
6	-	+	+	+	+	+	+	+	+
8	-	-	+	+	+	+	+	+	+
10	-	-	-	+	+	+	+	+	+
13	-	-	-	-	+	+	+	+	+
16	-	-	-	-	-	+	+	+	+
20	-	-	-	-	-	-	+	+	+
25	-	-	-	-	-	-	-	+	+
32	-	-	-	-	-	-	-	-	+
40	-	-	-	-	-	-	-	-	-

5 Conclusion

This work has created a table that would allow the selection of automatic breakers that are suitable for the conditions of full selectivity. Using the detailed table, you can select such AB on the branches so that the AB selectivity condition is met. Ensuring the condition of full selectivity will allow achieving continuity of power supply on the remaining branches in the event of a short circuit on the branch under consideration. From [10], a sufficient condition for choosing a device on the head section of the distribution network is a large switching capacity. Undoubtedly, the condition must be met given the manufacturer provides reliable data on the operation characteristics of the automatic breaker. From the provided characteristics, you can make an "overlay" of the time-current characteristics on one coordinate axis and look at the condition for performing "full selectivity". The characteristic usually does not affect the choice. It is important to meet the condition of "full selectivity".

6 Availability of Data And Material

Data can be made available by contacting the corresponding author.

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