LOW-VOLTAGE CIRCUIT BREAKER SELECTIVITY STUDIES

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Abstract. The article is devoted to the research of low-voltage circuit breaker (CB) series selectivity dependence on short circuit current and the manufacturer. The short circuit experimental tests were provided for three most widely used manufacturers' circuit breakers. Time-current curve classes B and C circuit breakers with current ratings of 16 A, 20 A, 25 A and 32 A were used. The research results prove that tripping times variate significantly between different manufacturers' circuit breakers – by 1.49-1.93 times. The circuit breaker series developed from one three-pole CB and one one-pole CB showed a possibility to provide total selectivity only at particular settings and moderate short circuit current. None of the CB series tested were able to provide total selectivity at high levels of short circuit current, just few of them showed partial selectivity. The research results prove that the use of different manufacturer MCBs in circuit breaker series connection needs to be analyzed carefully in order to provide selectivity and proper operation of the protection system.

Keywords: circuit breaker, selectivity, short-circuit, current, protection.

Introduction

Circuit breakers are essential devices to protect the electrical line from overcurrent in households and industrial facilities. There are different circuit breakers – air circuit breakers (ACBs), moulded case circuit breakers (MCCBs) and miniature circuit breakers (MCBs). The miniature circuit breakers are used for low voltage line protection.

With increasing amount of electrical energy consumption, there is a need for an uninterrupted power supply. Selectivity between two circuit breakers in series means, when short circuit (SC) occurs in the load side, the load side circuit breaker trips and the supply side circuit breaker remains closed guaranteeing supply to other installations. However, it is not always the case and there is significant amount of instances when selectivity is not provided, especially in places near substations. For example, short circuit current in a house that is significantly far from a power transformer is 88 A, but in a cafe in urban area SC current is 1902 A [1].

There is also variety of different circuit breaker manufacturers, time-current curve (TCC) classes and current ratings. Recent requirements established in the US as to total selectivity of protection devices lead to the research and development of new type selective miniature circuit breakers (SMCB) [2].

Complexity of the selectivity research increases with the fact that power electrical devices can interact with the miniature circuit breaker and increase the tripping time during a short circuit [3].

The aim of the study is to analyse the selectivity of different TCC and current rating circuit breakers.

Materials and methods

There are two standards that define miniature circuit breaker requirements – IEC 60898-1 and IEC 60947-2. Table 1 shows the main difference between IEC 60898-1 and IEC 60947-2 requirements for MCB [4; 5].

Table 1

Comparison between IEC 60898-1 and IEC 60947-2

MCB characteristics	IEC 60898-1	IEC 60947-2
Rated current, I_n	6-125 A	0.5-160 A
SC breaking capacity	< 25 kA	< 50 kA
Rated voltage, U_e	400 V	440 V, 500 V, 690 V
Impulse voltage, U_{imp}	4 kV	6 kV or 8 kV
Pollution degree	2	3
TTC	B, C, D	B, C, D, K, Z, MA
Application current	AC	AC or DC

Standard IEC 60898-1 defines requirements for MCB that are used in household installations designed for unskilled users and for devices not being maintained consequently. IEC 60898-1 MCBs rated current is not exceeding 125 A and 440 V (between phases). Standard IEC 60947-2 applies for industrial-use MCB, which are meant for skilled users and devices and do not exceed 1000 V AC or 1500 V DC, at 160 A.

Experimental research of selectivity of circuit breakers was performed on the test bench (Fig. 1) that consists of power supply, power transformer, current transducer, circuit breakers, digital oscilloscope and computer. Two circuit breakers were connected in series and directly to the power transformer secondary winding to form a short circuit.

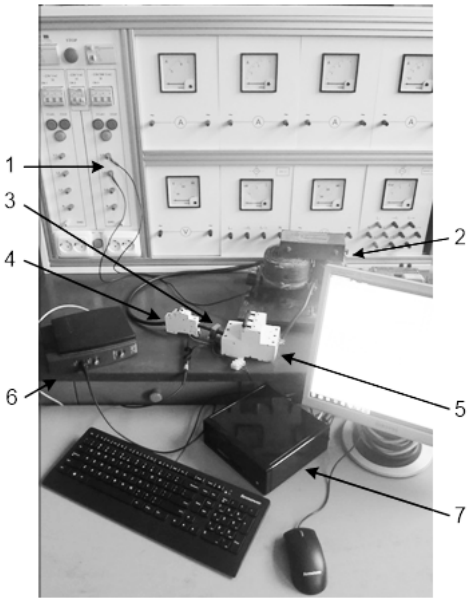

Fig. 1. **Test bench set-up for circuit breaker experimental research:** 1 – power supply; 2 – power transformer; 3 – current transducer; 4 – one pole circuit breaker; 5 – three pole circuit breaker; 6 – oscilloscope; 7 – computer

The tests were performed under the following short circuit currents – 300 A and 3000 A. Current transducer HAIS 400-P (accuracy ± 1 %) was used to measure the short circuit current. The output signal from the current transducer was registered by the Velleman PSCU100 digital oscilloscope. PCLAB2000SE software was used to setup settings for the oscilloscop to obtain and collect the measurement data.

Miniature circuit breakers (MCB) from three different manufacturers (in this paper mentioned as manufacturer A, B and C) were used. The choice of manufacturers was based on the data about the most often used MCB in Latvia low voltage grid.

The time-current curve classes B and C circuit breakers with current ratings of 16 A, 20 A, 25 A and 32 A were used. All circuit breakers that were used in the tests are IEC 60947-2 certified.

Two circuit breakers of each manufacturer were connected in series and in different combinations, (Table 2).

Table 2

Connection combinations of circuit breakers for experimental research

Short circuit current, A	Circuit breaker No.1 – Circuit breaker No. 2
300	C25 – B16; C25 – C16; C25 – B20; C25 – C20; C25 – B25; C32 – B16; C32 – C16; C32 – B20; C32 – C20; C32 – B25; C32 – C25
3000	C25 – B16; C25 – C16; C25 – B20; C25 – C20; C25 – B25; C32 – B16; C32 – C16; C32 – B20; C32 – C20; C32 – B25; C32 – C25

Two types of research were provided. First, one pole circuit breakers of each manufacturer B16; C16; B20; C20; B25 and C25 were tested to measure the tripping time for each single circuit breaker. Second, the selectivity study of the circuit breakers was done. The first (No. 1) circuit breaker was a three pole C25 or C32 and the second (No.2) circuit breaker was a one pole and changed with following curves and current ratings – B16; C16; B20; C20; B25 and C25.

Results and discussion

Experimental research data analysis shows that all tested MCB meet the time-current curve requirements according to IEC 60947-2.

The research results of the circuit breaker tripping times (Figure 2 – 3) show that tripping time depends on the magnitude of the short circuit current – at 300 A the tripping time is 1.3 – 2.1 times longer than at 3000 A.

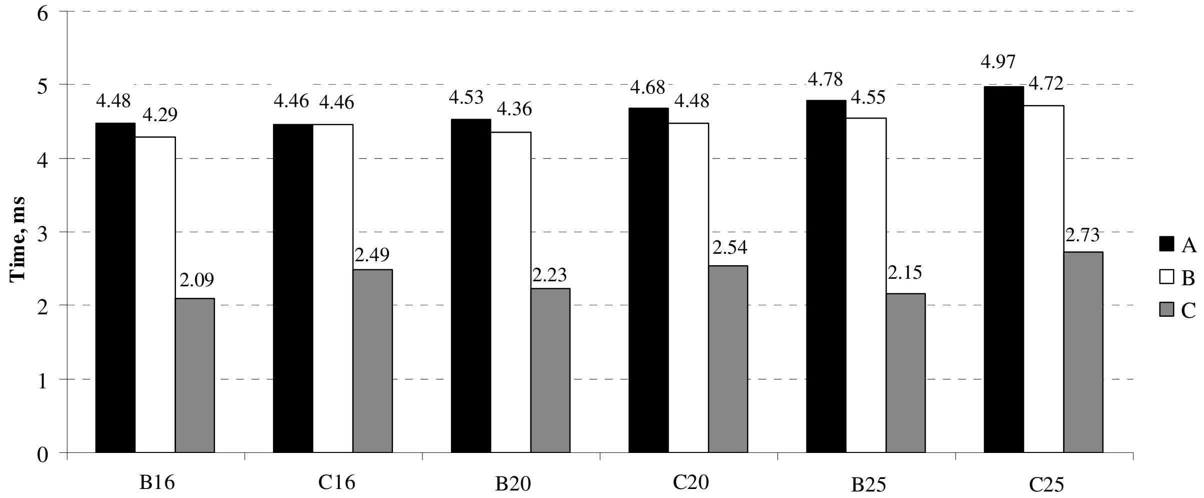

Fig. 2. **Tripping time of single circuit breaker under 300 A current**

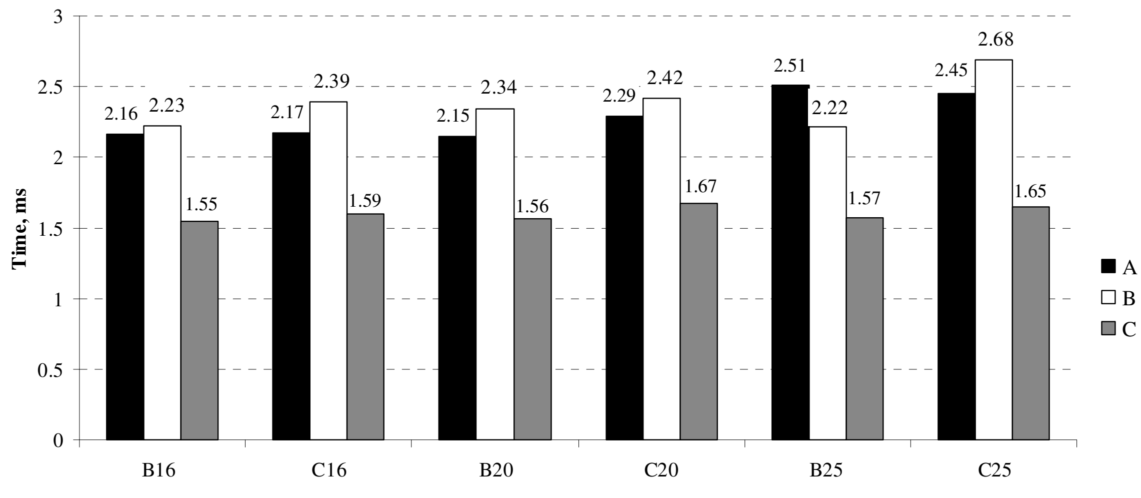

Fig. 3. **Tripping time of single circuit breaker under 3000 A current**

Insignificant tripping time difference was observed between the A and B type circuit breakers of the same manufacturer.

At the same time the tripping time differs significantly – data obtained from manufacturer C circuit breakers are significantly lower than the tripping times of manufacturer A and B circuit breakers. This relation is true for both short circuit currents – for 300 A and for 3000 A, e.g., at 300 A the tripping time $t_C = 2.37 \pm 0.253$ ms, in comparison with $t_A = 4.65 \pm 0.200$ ms and

$t_B = 4.48 \pm 0.151$ ms, and at 3000 A the tripping time $t_C = 1.60 \pm 0.050$ ms, in comparison with $t_A = 2.29 \pm 0.158$ ms and $t_B = 2.38 \pm 0.168$ ms.

In average, at 300 A SC manufacturer A and B MCB tripping time is 1.93 ± 0.170 times longer than manufacturer C MCB tripping time, and at 3000 A SC manufacturer A and B MCB tripping time is 1.46 ± 0.007 times longer than manufacturer C MCB tripping time.

Selectivity experiment results show that the tripping time of three pole C25 and one pole B16, C16, B20, C20, B25 circuit breakers connected in series (Fig. 4-5) show significant difference. Manufacturer A and B circuit breakers have close tripping speed ($t_A = 7.11 \pm 0.236$ ms and $t_B = 6.88 \pm 0.280$ ms for 300 A SC, and $t_A = 4.67 \pm 0.123$ ms and $t_B = 4.63 \pm 0.162$ ms for 3000 A SC), at the same time manufacturer C circuit breakers trip is significantly faster ($t_C = 2.37 \pm 0.233$ ms for 300 A SC and $t_C = 1.64 \pm 0.070$ ms for 3000 A SC).

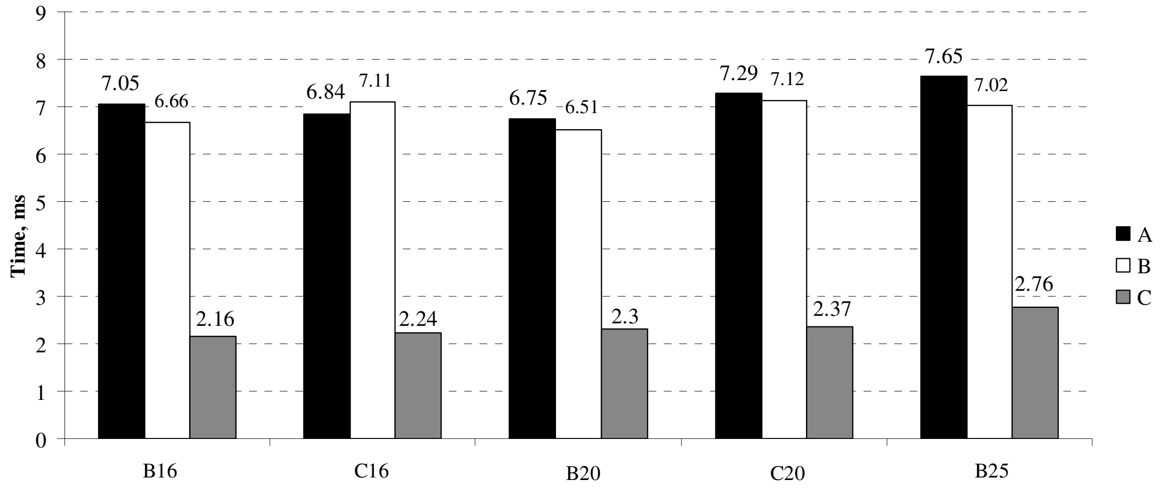

Fig. 4. **Tripping time of three pole C25 and single pole circuit breakers under 300 A current**

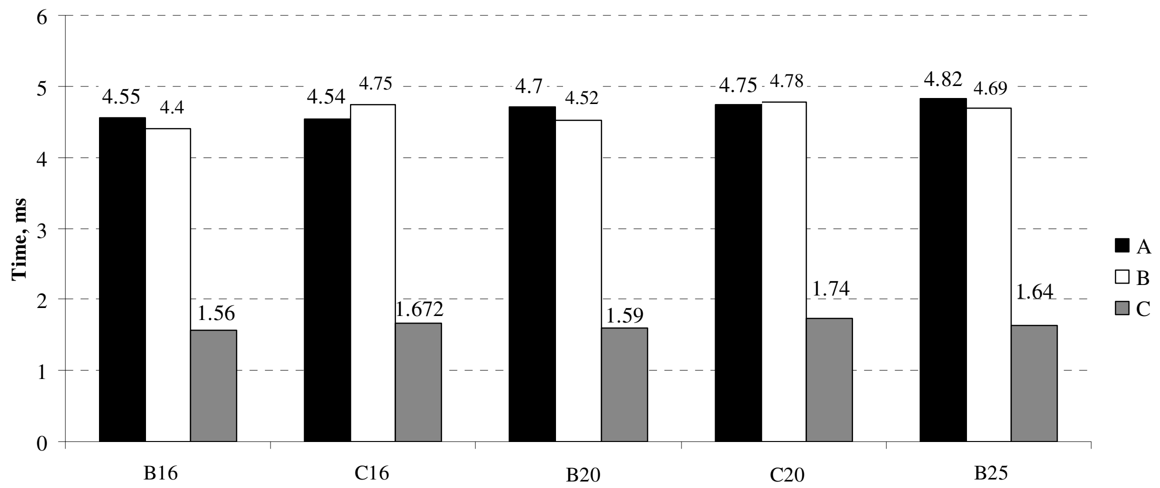

Fig. 5. **Tripping time of three pole C25 and single pole circuit breakers under 3000 A current**

In average, manufacturer A and B MCB tripping time for three pole C25 and one pole B16, C16, B20, C20, B25 MCB connected in series is 2.89 times longer than manufacturer C MCB tripping time.

Tripping time tests results (Fig. 6 – 7) for three pole C32 and single pole B16 – C25 circuit breakers are having similar data structure as the three pole C25 and single pole B16 – B25 results. However, the tripping times are slightly higher for three pole C32 and single pole B16 – C25 circuit breakers.

In average, manufacturer A and B MCB tripping time for three pole C32 and single pole B16 – C25 circuit breakers connected in series is 2.74 times longer than manufacturer C MCB tripping time.

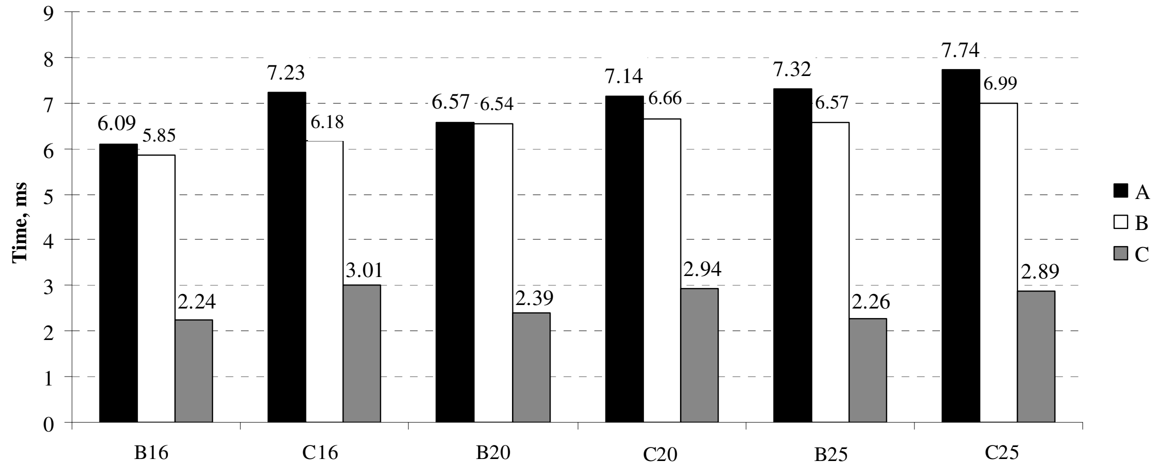

Fig. 6. **Tripping time of three pole C32 and single pole circuit breakers under 300 A current**

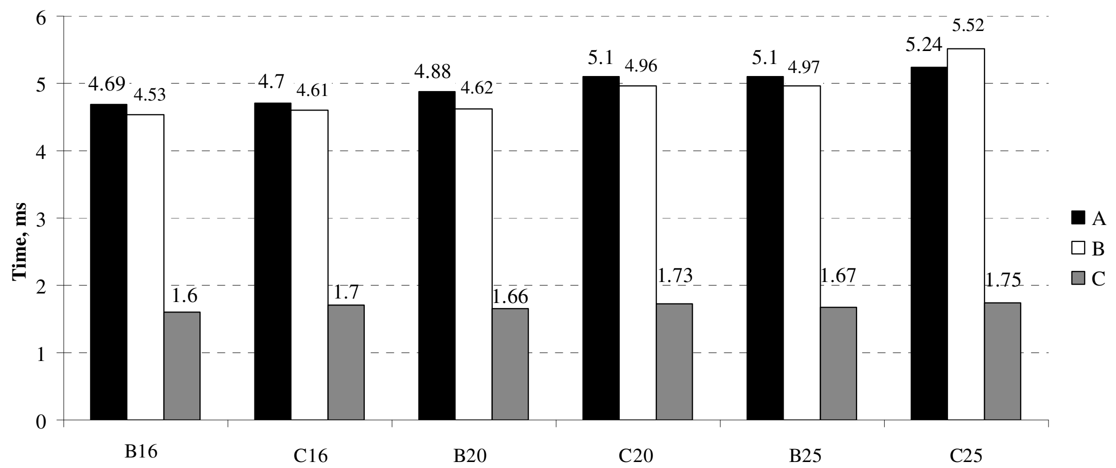

Fig. 7. **Tripping time of three pole C32 and single pole circuit breakers under 3000 A current**

The selectivity of different circuit breaker connection in series combinations is presented in Table 3.

Table 3

Selectivity and tripping time of circuit breakers under 3000A short circuit

Circuit breaker No. 1	**Manu-facturer**	**Current, A**										
		300					3000					
		Circuit breaker Nr. 2					Circuit breaker Nr. 2					
		B16	C16	B20	C20	B25	B16	C16	B20	C20	B25	C25
C25	A	PS	PS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	B	PS	PS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	C	PS	PS	NS	NS	NS	PS	NS	NS	NS	NS	NS
C32	A	*TS*	*TS*	NS	NS	NS	NS	NS	NS	NS	NS	NS
	B	*TS*	*TS*	NS	NS	NS	PS	NS	NS	NS	NS	NS
	C	*TS*	*TS*	*TS*	PS	PS	PS	NS	NS	NS	NS	NS

TS – total selectivity; PS – partial selectivity; NS – no selectivity

C32 – B16 and C32 – C16 circuit breaker connection combinations tested by 300 A short circuit current proved that MCB from all manufacturers provided total selectivity (only single pole circuit breaker tripped). At the same time C32 – B20 circuit breaker connection combination only for manufacturer C MCB provided total selectivity.

Partial selectivity (in 20-40 % cases only single pole circuit breaker tripped), was provided by all manufacturer C25 – B16 and C25 – C16 circuit breaker connection combination. Similarly as in the previous set, circuit breakers for manufacturer C differ significantly – they provide partial selectivity also in C32 – C20 and C32 – B25 circuit breaker connection combination.

For 3000 A short circuit current none of the manufacturers and MCB combinations were able to provide total selectivity. Partial selectivity (20 %) was provided in C32 – B16 circuit breaker connection combination for manufacturer B and C, and in C25 – B16 circuit breaker connection combination for manufacturer C.

The experiment analysis allows to state also that manufacturer C circuit breakers with the same curve class and current rating provide better selectivity than that of manufacturers A and B.

Conclusions

1. Although all tested MCB meet the time-current curve requirements according to IEC 60947-2, the test results show significant tripping time difference between different manufacturer MCBs –the tripping time difference is 1.46-1.93 times depending on short circuit current and the manufacturer.
2. C32 – B16 and C32 – C16 circuit breaker connection combinations tested by 300 A short circuit current proved that MCB from all manufacturers provided total selectivity. At the same time, the tripping time difference for different manufacturers is substantial – 2.74 times.
3. Partial selectivity (in 20-40 % cases only single pole circuit breaker tripped) was provided by all manufacturer C25 – B16 and C25 – C16 circuit breaker connection combination.
4. For large short circuit current (3000 A) none of the manufacturers and MCB combinations tested were able to provide total selectivity.
5. The use of different manufacturer MCBs in circuit breaker series connection needs to be analyzed carefully in order to provide selectivity. The MCBs with shorter tripping time need to be placed closer to the load side to provide selectivity.

References

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