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LET-THROUGH ENERGY OF MINIATURE CIRCUIT BREAKER IN FUNCTION OF PHASE ANGLE OF SHORT-CIRCUIT CURRENT

Let-through energy (Joule heat) is an important factor in proper protection of electrical installations and devices. Studies were preformed during which the relationship between amount of energy and phase angle of short-circuit current was examined. Typically used miniature circuit breaker was utilized as a protective device. Scilab software for numerical computation was used to calculate the let-through energy based on recorded oscillograms of short-circuit current. Results of this calculations are presented.

KEYWORDS: MCB, let-through energy, Joule's heat

1. MINIATURE CIRCUIT BREAKERS CONSTRUCTION

Figure 1 shows schematically the main parts of a low voltage circuit breaker and its four essential functions [1]:

- circuit-breaking components, comprising the fixed and moving contacts and the arc-dividing chamber,
- latching mechanism which becomes unlatched by the tripping device on detection of abnormal current conditions, this mechanism is also linked to the operation handle of the breaker,
- trip-mechanism actuating device:
  - either: a thermal-magnetic device, in which a thermally-operated bi-metal strip detects an overload condition, while an electromagnetic striker pin operates at current levels reached in short-circuit conditions, or
  - an electronic relay operated from current transformers, one of which is installed on each phase,
- space allocated to the several types of terminal currently used for the main power circuit conductors.

Use of miniature circuit breakers (MCB) as protection devices for electrical installations is required by Polish law [2].

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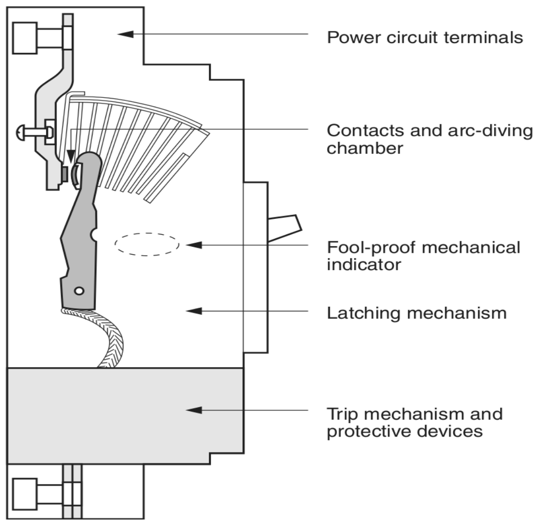

Fig. 1. Main parts of a circuit breaker

Miniature circuit breakers are used as protection devices against overload and short-circuit currents. Basic principles on how to protect electrical circuits and devices against this hazards are known and described in many publications [3, 4]. However there are not many information on the influence of phase angle on short-circuit current and the let-through energy (Joule heat).

2. TEST CIRCUIT AND RESULTS

Joule heat is the energy in joules liberated in one ohm of resistance in a circuit protected by a fuse is equal to the value of the operating I^2t expressed in A^2•s [5]. In is also referred to as let-through energy as a parameter used for proper selection of protecting device for electrical installations (eq. 1).

$$\int i^2 dt \left[\mathrm{A}^2\mathrm{s}\right] \tag{1}$$

In order to evaluate the relation between phase angle and the let-through energy a test circuit was created (Fig. 2). Its main parts were a miniature circuit breaker, with nominal current of 16 amperes and B-type characteristic, an electromagnetic relay, used to close the circuit, and a synchronization device, which enabled to close the circuit at a specific phase angle. Parameters of test circuit are presented in Table 1. Test circuit was measured using a Metrel MI 2086 EUROTEST 76155 multifunctional digital measuring instrument for low voltage electrical installation safety. Prospective current was set close to a value of 10 I_N of used MCB. The circuit has a high power factor of 0,998, so we can treat that supply voltage and current are phase alainged.

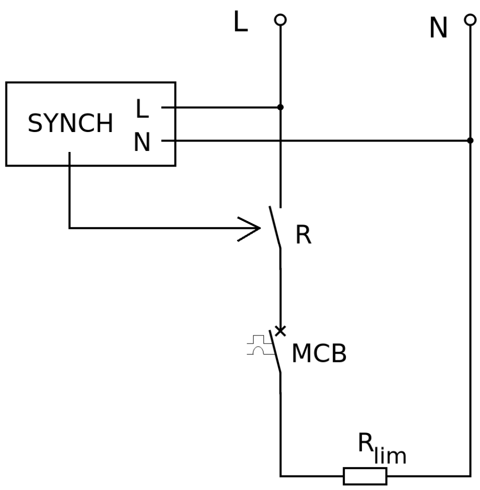

Fig. 2. Test circuit schematic: R – electromagnetic relay, MCB- miniature circuit breaker, R_{lim} – limiting resistor, SYNCH – phase synchronization device

Table 1. Test circuit parameters

Impedance Z	Reactance X	Resistance R	Prospective current I_K	Power factor cos φ
[Ω]	[Ω]	[Ω]	[A]	[-]
1,49	0,08	1,49	162	0,998

For each of nine arbitrary selected phase angles five test were conducted. Using a GDS-3154 digital oscilloscope and HAMEG HZO51 current probe the short-circuit current was measured. Acquired data was then processed in Scilab as described in [6]. For each set phase the let-through energy (Joule heat), maximum current and short-circuit times were calculated. Average values obtained are presented in Table 2. Selected current-time oscillograms for different set phase angles are presented on Figure 3.

For five phase angels: 20º, 40º, 60º, 80º and 100º short-circuit time was in range between 10 and 4,5 ms, with shorter times observed for higher phase angles. This can be correlated with current reaching zero value every 10 ms and thus the MCB can break the short-circuit current naturally. For 120º, 140º and 160º short-circuit time often exceeded 10 ms. It can be assumed that there is a relationship between this fact and the miniature circuit breaker opening time. Since the main contacts of MCB haven't started to open there is no contact gap.

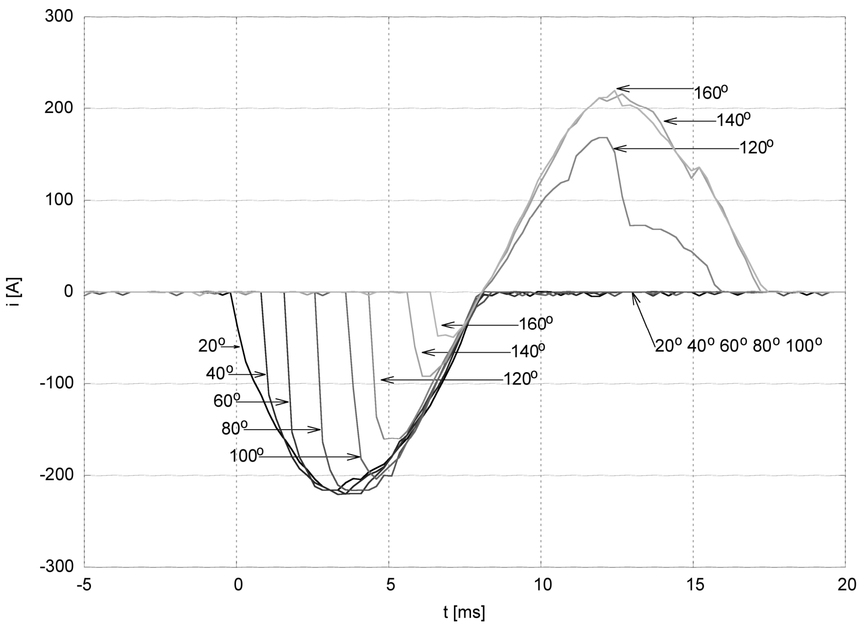

Fig. 3. Short-circuit current graph for different set starting phase

Table 2. Average values of let-through energy, maximum current and short-circuit time for different set starting phase

Phase angle	Let-through energy $\int i^2 dt$	Max current *i*	Short-circuit time t_Z
[°]	[A^{2}s]	[A]	[ms]
0	201,03	217,08	9,85
20	197,55	218,03	9,11
40	190,84	219,60	10,98
60	176,61	220,16	8,11
80	138,93	217,64	7,48
100	87,70	205,97	4,54
120	116,43	183,69	8,85
140	204,62	218,12	11,57
160	195,04	217,14	11,00

There is also a requirement that the current reaches at least value of 80 amperes in order to trigger the circuit breaker mechanism. For high phase angles that isn't always true. Summing the above statements the break process for high phase angles may start after the current reaches zero. This also explains higher short-circuit current times.

With this higher times the let-through energy rises, according to eq. 1. Figure 4 presents the relationship between let-through energy and phase angle of short-circuit current.

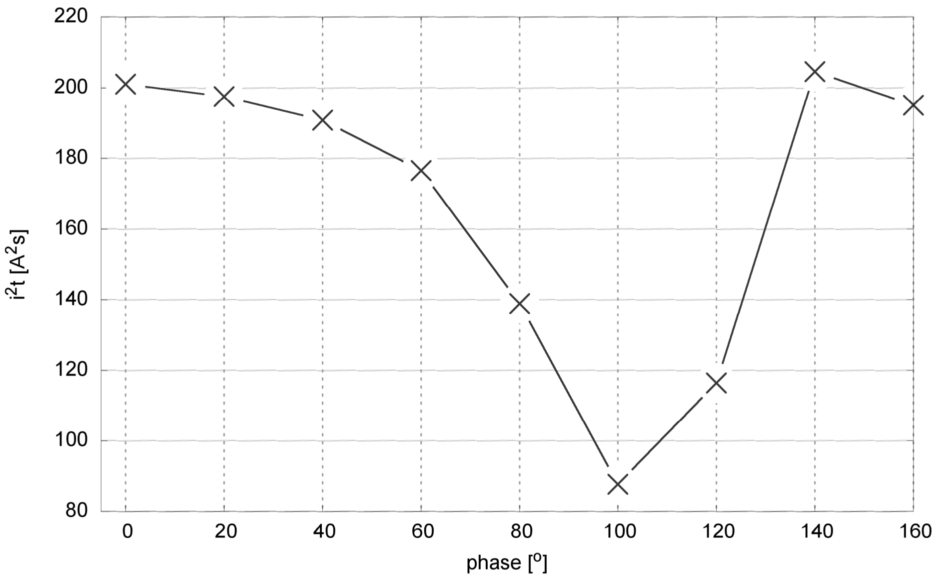

Fig. 4. Average value of let-through energy for different set starting phase

It can be seen that, similar as with short-circuit time, Joule heat reaches lower values for higher phase angles up to 100°. With higher short-circuit times let-through energy rises. For phase angles up to 40° the difference between energy level is minimal.

Different conclusions can be drawn for the maximum short-circuit current values, as there is no apparent relation between its value and the phase angle. Because there is little or none inductance in the circuit short-circuit current can reach high values almost instantly, phased with source voltage value. This can be observed on figure 3 for short-circuit current oscillograms for 40° to 160°. At the beginning for short-circuit the current values rises fast in a very short time.

3. CONCLUSION

Use of miniature circuit breakers is obligatory so it seems important to know every aspect of how they work. There is a clear relation between phase angle and the let-through energy (also true for short-circuit time). High values of Joule heat can be observed for low, between 0º and 60º, and high, above 140º, phase angles. That means the thermal effects for the electrical circuit and devices protected by MCB differ with different phase angle and this relation isn't linear. However there is no obvious change of maximum short-circuit current value with change of phase angle.

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