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Andrzej KSIĄŻKIEWICZ*
Jerzy JANISZEWSKI*
Ryszard BATURA*

INFLUENCE OF SHORT-CIRCUIT AC CURRENTS ON ELECTRICAL CONTACT RESISTANCE OF LOW VOLTAGE RELAYS

Electromagnetic relays can be exposed to many hazardous phenomena during their lifetime. The most vulnerable part of an relay to their adverse effects are his electrical contacts. One of many parameters describing electrical contacts is their resistance. In this article experiments regarding the impact of short-circuit currents at make on electrical contact resistance of electromagnetic relays is described.

1. ELECTRICAL CONTACT RESISTANCE AS A QUALITY INDICATOR

Every electromagnetic relay is characterized by many factors such as [1]: rated current, electrical life at rated current and power loss to the environment at rated current. The last parameter depends on the value of electrical contact resistance (ECR). Because contact resistance depends on many factors its value can't be easy determined by theoretical calculations.

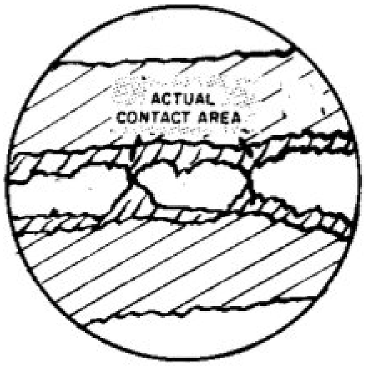

Fig. 1. Magnification of electrical contact surface created for a model in [4]

* Poznan University of Technology.

Some of these factors are the material from which contacts are made, the process in which they are made, environment in which they operate (air, vacuum), etc. An important factor is roughness of the surface, which determines the amount of contact points on the contact surface (Fig. 1). This last parameter changes over time as the relay is used and exposed to many different phenomenons, such as: contact bounces at make operations [2], pre-arcs, short-circuit currents, arc erosion [3] and others. Both the amount of contact points and their area can change over time. That change will influence the value of ECR. By measuring it we can try to determine the condition of relay contacts. A high enough value can indicate that a relay needs to be replaced.

2. TEST SET UP FOR SHORT-CIRCUIT CURRENTS AND ECR MEASUREMENTS

2.1. Short-circuit current test

The purpose of this test was to acquire experimental data regarding how a short-circuit current can influence electrical contacts and their resistance. Test circuit used for this experiment is presented on Fig. 2. A 400 amps prospective current was set with a 0,99 power factor.

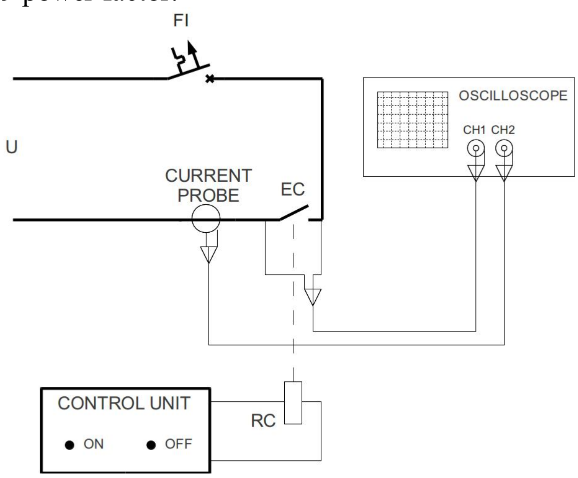

Fig. 2. Test circuit for short-circuit current measurements: EC – electrical contacts, RC – relay coil, FI – modular circuit breaker

The measurement apparatus consisted of a modular circuit breaker (MCB) FI, electromagnetic relay, a current probe and a voltage probe. The test circuit included a control unit, used to turn on and off the relay under test. Two different MCB were used in the experiment. The first one was an MCB with B-type time-current characteristic and a 16A rated current and the second one was an MCB with C-type time-current characteristic and a 32A rated current. The current probe provided 1 mV output for each amp measured. A 100:1 voltage probe was used for registering voltage drop between electrical contacts of tested relay. Both current and voltage were stored using a digital oscilloscope.

There were twenty-nine tests concluded on five electromagnetic relays. The relays used in these tests were rated for a 16A current, and their electrical contacts where made from AgCdO.

For each test the voltage between and current flowing through the relays contacts where acquired using an oscilloscope. The data was stored and then used to evaluate the amount of energy that was let-through by the modular circuit breaker. An example oscillogram of registered short-circuit current and voltage is presented on Fig. 3.

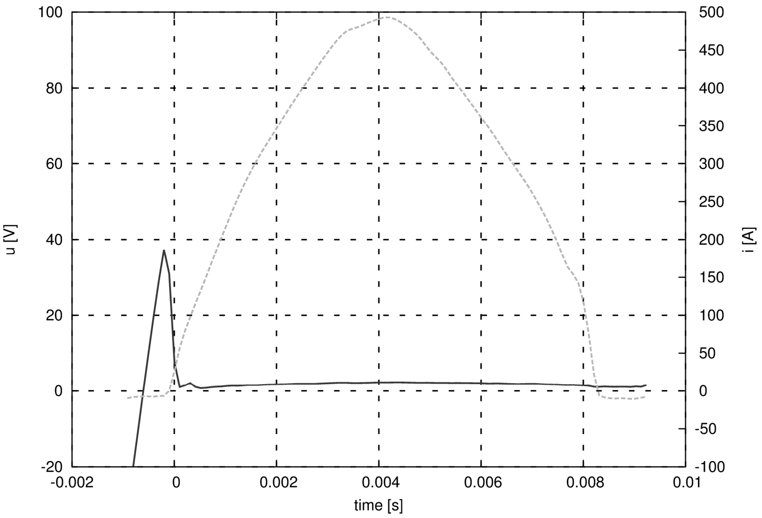

Fig. 3. Oscillogram of voltage between contact (solid line) and short-circuit current (dotted line)

2.2. Electrical contact resistance test

After performing short-circuit tests the electrical contact resistance for each relay used in the experiment was measured. The test circuit is presented on fig. 4. The measurement apparatus included an relay coil RC and its electrical contacts EC, current limiting resistor R, ammeter A, voltmeter V and a DC power supply. The same control unit as in previous experiment was used. The current limiting resistor R together with the DC power supply were used to set a 10A DC current. For each relay the ECR was tested three times, turning it on and off for each test. Both the voltage drop and DC current where recorded and the ECR was calculated.

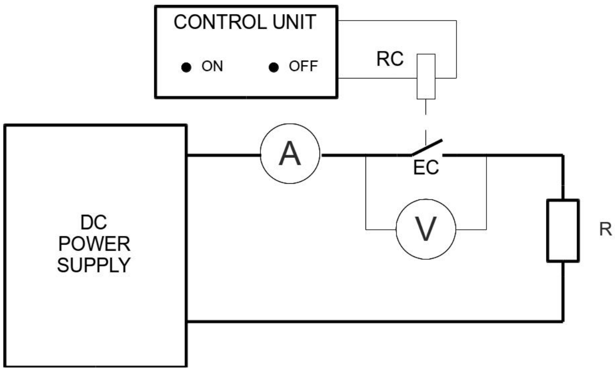

Fig. 4. Electric contact resistance measurement circuit: EC – electrical contacts, RC – relay coil, A – ammeter, V – voltmeter, R – current limiting resistor

3. ANALYSIS OF ACQUIRED RESULTS

The test results are presented in Table 1. It consists of the following elements: number of tests concluded on a single relay, number of make contact bounces observed during all the tests, number of pre-contact arc observed, the sum of all the let-through energy generated during the test and an average of electric contact resistance after the tests.

Table 1. Results of short-circuit and electric contact resistance measurements

Tested relay	Number of test conducted	Number of contact bounces at make observed	Number of pre-contact arcs recorded	Sum of let-through energy	Average of ECR after tests
	[-]	[-]	[-]	[A^2s]	[mΩ]
1	4	2	2	4507,61	1,13
2	11	5	9	8451,74	1,37
3	8	3	5	6673,86	0,77
4	6	2	5	4118,00	1,03

The pre-contact arc is a phenomenon that occurs just before the electrical contacts close. If voltage between the contacts is high enough and the distance between contacts is very small an electrical arc appears, which can last just a few microseconds and disappears after the contacts close. This phenomenon is called pre-arcing.

The electrical contact resistance of an unused relay is 0,6 mΩ. It is clear that in effect of a short-circuit currents value of ECR after tests rises, even almost 2,3 times. This gain in value occurred for the second relay, which was the most exposed one during the test. It was the most tested one, both make bounces and pre-arc phenomenons were observed in highest amount and the let-through energy was also highest. However it is not always the case that more tests result in higher ECR value. By comparing the results for first and third relays it is clear that the latter was under bigger electrical stress, by which it means that more make bounces and pre-arcs occurred during those tests. And in spite of this the resulted ECR was higher for the first relay, which was used in fewer tests.

4. RESULT ANALISYS

By comparing the number of contact bounces at make, pre-contact arcs and the sum of let-through energy individually a single conclusion cannot be determined. None of the recorded factors has such a high impact on the electrical contact resistance that it can be examined individually. For example higher count of pre-arcs doesn't result in higher ECR value. However since none of the observed phenomenons can appear without the others they can't be examined separately.

In all the tests electric contact resistance value has risen. This may lead to increased temperature of relays contacts above the designed specifications.

5. CONCLUSION

Electrical contact resistance is a parameter that can be used to asses the state of a relay contact. Usage of the relay in both normal and abnormal conditions, such as conducting short-circuit currents, may have an impact on the ECR value. By measuring it the state of relay contacts can be assessed. Increased ECR may indicate that contacts, and probably the whole relay, needs to be replaced. However clear guidelines on when the relay should be replaced are necessary.

REFERENCES

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