

Arc Reduction Methodology of Circuit Breaker Damaged by Series-Arc

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Abstract

Objectives: The temperature rise characteristic of a circuit breaker connector resulting from a series-arc caused by faulty contact was analyzed along with a proposed method to mitigate such series-arc. **Methods/Statistical Analysis:** Variable current load was applied to the screw connector of the circuit breaker to perform a test on the temperature characteristic using an arc generator when the screw-type connector of the circuit breaker is under one of the following conditions: Normal contact, faulty contact, and with an insulating pad. The results under the respective conditions were analyzed and compared. **Findings:** It was confirmed that the temperature in the connector can rise rapidly due to an arc, possibly resulting in a fire if an excessive load is applied to the circuit breaker with a faulty contact in the screw attributed to a slight gap between the screw and connector. Therefore, such fire can be prevented by inserting an insulating pad in the connector. **Improvements/Applications:** The findings of this study are believed to be helpful in preventing fires resulting from a series-arc, establishing regulations for the installation of arc fault circuit interrupter and studying an investigative method for fires resulting from a faulty contact.

Keywords: Arc Reduction Methodology, Circuit Breaker, Electric Fire, Poor Contact, Series-Arc

1. Introduction

About 75% of all electric fires triggered by short circuit, overcurrent, poor contact or tracking are caused by short-circuit failure. Those triggered by overcurrent or poor contact in connectors account for some 10%^{1,2}. Once a fire by poor contact starts to spread, it soon damages the sheath of electric wires, consequently resulting in a complex electric accident that induces a secondary short circuit or ground^{3,4}.

As for the Arc Fault Circuit Interrupter (AFCI) that shuts down power after detecting an arc wave form, Robert G. Schena of the United States invented one and named it Electrical Fire Hazard Detector. In South Korea, HETKO developed one tailored for the unique environment of the country. Numerous research papers on the arc wave detection method have been published, prompting active studies on fire prevention⁵⁻⁹ and Fuse development¹⁰.

However, few systematic studies have been performed on the fire outbreak mechanism by poor contact. It is therefore necessary to identify the key causes of such electric fires and develop methods and measures for detecting such occurrence to reduce and prevent damage from an electric fire¹¹.

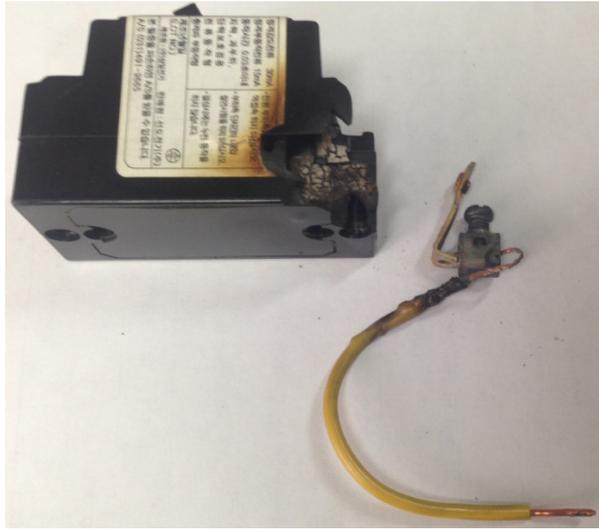
This study sought to analyze the temperature rise characteristic of the circuit breaker connector attributed to the occurrence of a series-arc in an attempt to analyze the overload mechanism that leads to an electric fire from an arc due to a poor contact.

2. Fire by Poor Contact

Fires by poor contact break out mostly in connectors including the consent, connecting section of circuit breaker and terminal pad. Fires would soon escalate to

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flames as inflammable substances surrounding the heated section catch fire.



(a)



(b)

Figure 1. Practices of poor contact. (a) Circuit breaker. (b) Outlet.

Figure 1 shows a case of poor contact that occurred in a residential home. In Figure 1(a), the area surrounding the connector of the circuit breaker was carbonized owing to a poor contact in the connector of the circuit breaker installed on the panel board; the sheath of the connected wire melted and part of the wire became thinner due to oxidization. In Figure 1(b), the surrounding area was carbonized since load was incompletely applied to the consent. It would be possible to determine whether

there indeed was a poor contact if such cases did not lead to a fire, but if the debris was damaged by the fire, it would be practically impossible to determine it with the naked eye. Furthermore, since the current flowing in the event of a poor contact is lower than the trip current flowing through the circuit breaker, secondary electric melting scar can be retained anytime when the power was not shut down. This would lead people to believe that the fire was triggered by a short circuit or current leakage. Causes of fires by poor contact can be classified mainly into two types: Fire outbreaks due to rising contact impedance triggered by momentary faulty contact or presence of foreign substance; and those by miniscule high-temperature arcs by a poor contact caused by breeding heat of cuprous oxide.

3. Test and Result Analysis

3.1 Test Method

A test rig as shown in Figure 2 was devised to analyze temperature rise characteristic of the screw-type connector of the circuit breaker owing to a series-arc. The test rig was composed of MCCB, ELB, variable resistance, thermographic camera, thermoscope, and notebook computer. The test was performed using single phase 220[V] 60[Hz] commercial electricity while the current level was controlled by using a variable resistor since the trip current flowing through the circuit breaker is 20A in general.

To measure in real time the temperature in the wires and connector of the circuit breaker at the moment of arc occurrence, a thermo graphic camera was installed along with a thermoscope for secondary measurement. To check the load current, a clamp meter was installed while heat resistant indoor PVC insulated wire (HIV) 2.5 mm² was used for the circuit breaker.

ELB2P50A (5KA) was used to break open the connector in order to allow easier observation of the poor contact in the connector of the circuit breaker. The gap between the arc-generating electrodes was adjusted down to some 0.1 mm until the arc was being generated consistently in the connector of the circuit breaker. The test condition was set at 24A load current as it was judged that an arc would not transpire significantly in the case of normal contact as shown in Table 1. The temperature of the screw-type connector of the circuit breakers was measured for 10 minutes by changing the load current from

6A, 12A, 18A to 24A under the following conditions: contact gap of the upper pad tightened down to 0.1 mm with an insulation pad inserted.

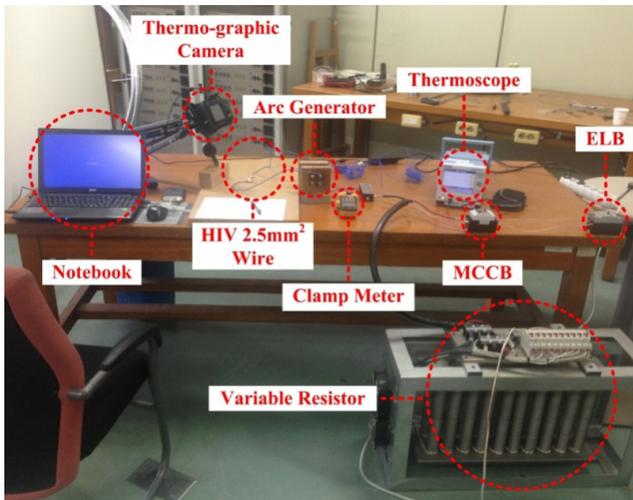


Figure 2. Construction of test system.

Table 1. Conditions of test

Contact Condition	Load Current [A]	Test Time [minute]
normal contact	24	10
Upper pad contact (0.1mm tightened)	6,12,18,24	10
Upper pad contact (0.1mm tightened) (inserted insulationpad)	6,12,18,24	10

3.2 Analysis and Discussion of Test Results

Figure 3 shows that the temperature in the contact rose up to MAX 33°C when it was measured for 10 minutes after applying 24A current in the case of normal contact. 1



(a)



(b)

Figure 3. Test result of normal contact. (a) Sample. (b) Temperature characteristics.

Figure 4 shows results when load current was changed from 6A to 24A with the upper pad of the connector tightened down to 0.1 mm. Figure 4(a) shows a sample with the upper pad of the connector tightened down to 0.1 mm. Figure 4(b) shows that the temperature in the connector rose to MAX 447°C after application of 6A current. It is believed that electric vibration generated by the Coulomb force, which was exerted up and down on the wires between the upper and lower pads of the connector, exerted an influence on arc generation.

Figure 4 (c) shows that an arc was generated after application of 12A current while the temperature in the connector rose to MAX 627°C. Figure 4(d) shows that the temperature in the connector rose to 651°C, which is well past the measurement limits of the thermal imaging camera, after application of 18A current. Figure 4(e) shows that the temperature in the connector rose to 670°C, which is well past the measurement limits of the infrared camera, consequently heating the wires until it burned to red after application of 24A current.

Figure 5 shows results that were observed when the load current was changed from 6A to 24A with the contact gap between the upper pad and wires insulated so that the gap should be kept at 0.1 mm. Figure 5(a) shows a sample with the upper pad of the connector tightened to 0.1 mm (insulator inserted).

Table 2 shows the results of a temperature rise test when the connection status of the screw-type connector was adjusted to the following conditions, respectively: Normal contact; contact gap of the upper pad tightened to 0.1 mm; and contact gap of the upper pad tightened to 0.1

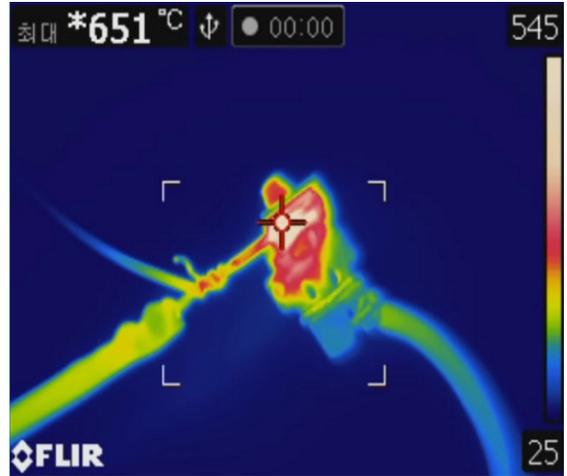
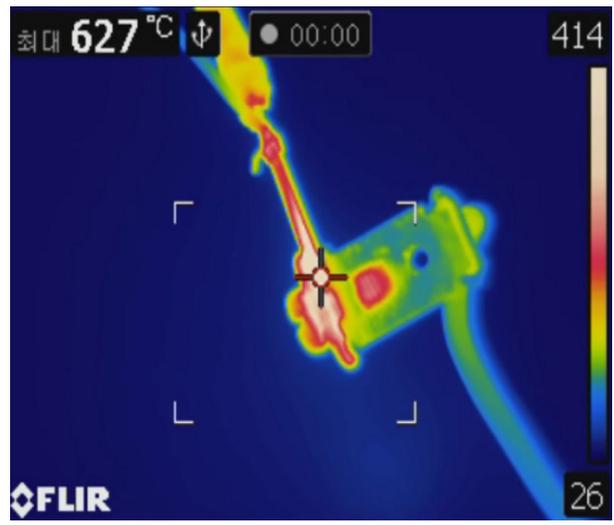
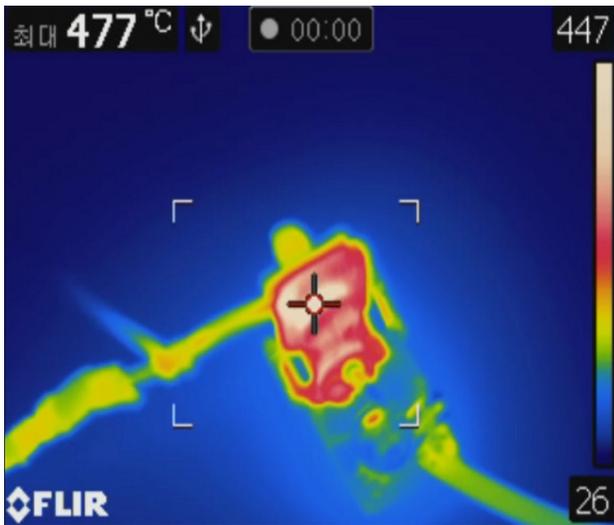
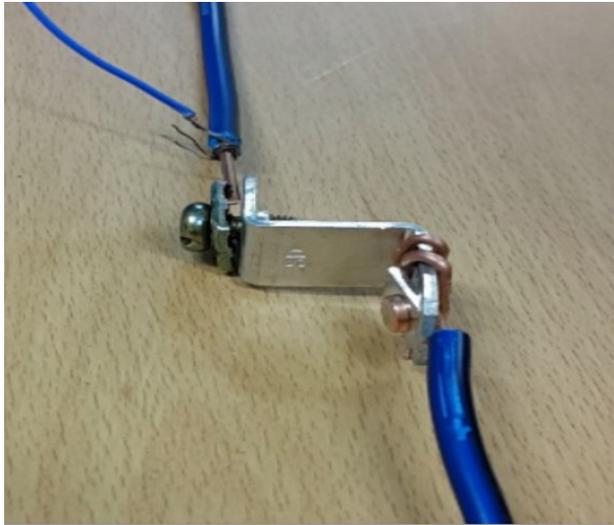
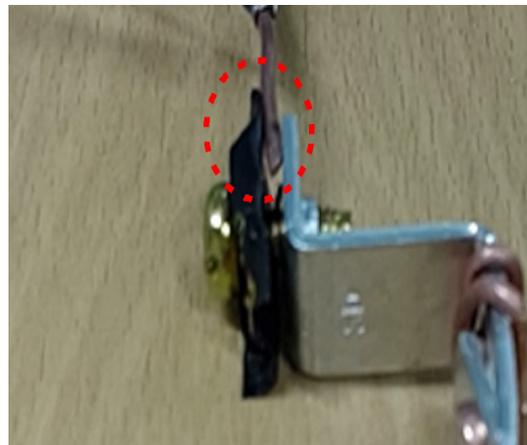
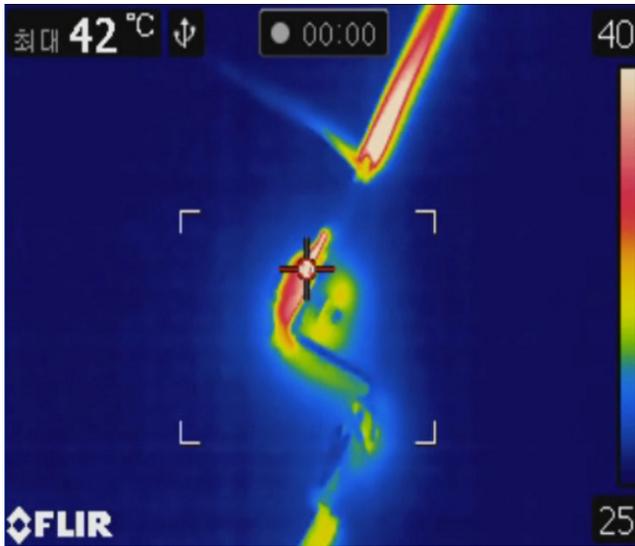
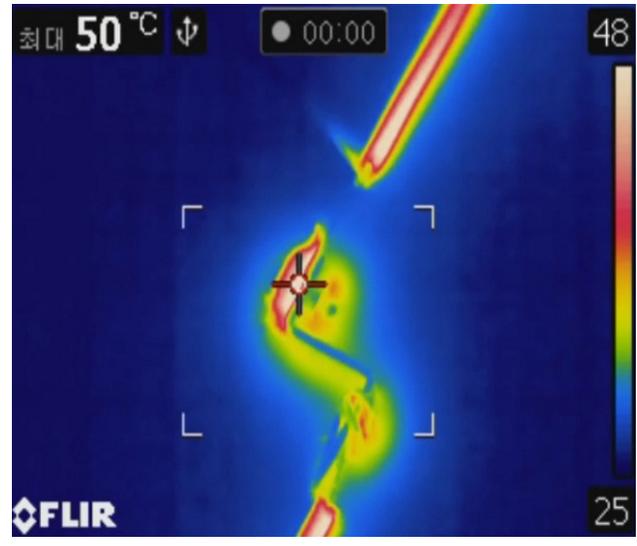


Figure 4. Test Results of upper padcontact (0.1mm tightened). (a) Sample. (b) Temperature characteristics (6A). (c) Temperature characteristics (12A). (d) Temperature characteristics (18A). (e) Temperature characteristics (24A).

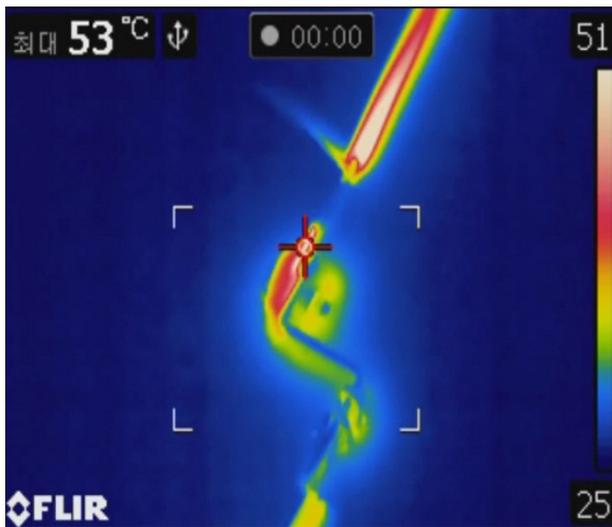




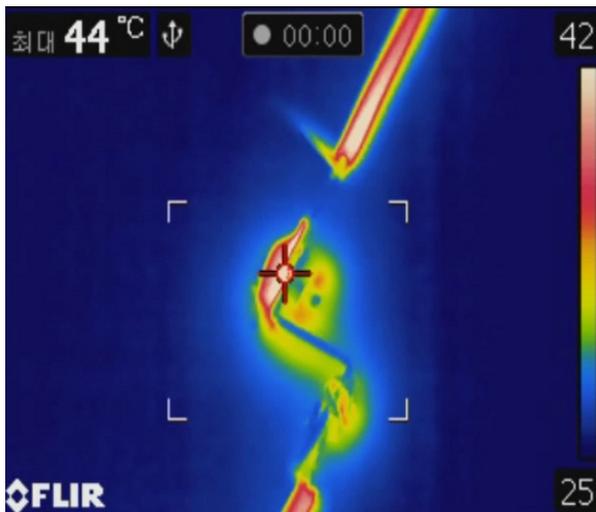
(b)



(e)



(c)



(d)

Figure 5. Test results of upper padcontact (0.1mm tightened/ inserted insulation pad). (a) Sample. (b) Temperature characteristics (6A). (c) Temperature characteristics (12A). (d) Temperature characteristics (18A). (e) Temperature characteristics (24A).

Table 2. Analysis of test results

Contact Condition	Load Current [A]	Max. Temp. []
normal contact	24	33
upper padcontact (0.1mm tightened)	6	477
	12	627
	18	651
	24	670
upper padcontact (0.1mm tightened) (inserted insulation pad)	6	42
	12	53
	18	44
	24	50

mm (insulation pad inserted). It was confirmed that the stronger the load current becomes, the higher the MAX temperature rises when the contact gap of the upper pad was tightened to 0.1 mm. The result confirms that temperature could rise more rapidly as compared to normal contact situation, thereby potentially triggering an electric fire. In the case where the contact gap of the upper pad (insulation pad inserted) was tightened to 0.1 mm, it was confirmed that the temperature in the connector was maintained stably as in the case of normal contact. Continuous arc generation can be suppressed by inserting an insulation pad.

4. Conclusion

In this paper, the temperature rise characteristic of the screw-type connector caused by a faulty contact in the connector was analyzed along with proposed measures that would prevent electric fires.

If overcurrent is being applied consistently to the connector when there is poor contact due to a gap between the screw and contact, the temperature in the connector rises rapidly due to an arc, potentially resulting in an electric fire. Such arc generation can be prevented even if overcurrent is being applied consistently to the circuit by inserting an insulator in the screw-type connector of the circuit breaker. This confirms that the rise in temperature could be as stable as in the case of normal contact.

This paper would be useful as a reference source for establishing measures to prevent fires from a series arc; studying improvement of screw-type electric connectors; and implementing a method to investigate fires triggered by poor contact.

5. Acknowledgements

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6. References

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