Case study #	2.9
Title	Malfunction of circuit breaker due to lightning surges
Type of trouble	Abnormal operation.
Source of trouble	Lightning.
System affected	Access system.
Location	Outdoors.
Keywords	Safety, immunity, lightning, power transmission line, circuit breaker, MOV.
Version date	2004-01-01

System configuration

The circuit breakers in the power units of an access network system located outdoors malfunctioned due to lightning. The access network system had an optical fibre cable, which was connected to centre equipment, a metallic subscriber cable, and an AC mains line (Figure 2.9-1). The system had four power units. Each unit had a circuit breaker, with a capacitance of 5 A at the AC mains frequency. Figure 2.9-2 shows the system's protection circuits. The power units are produced by two manufacturers. Their circuits were almost the same, but they had different malfunction occurrence probabilities.

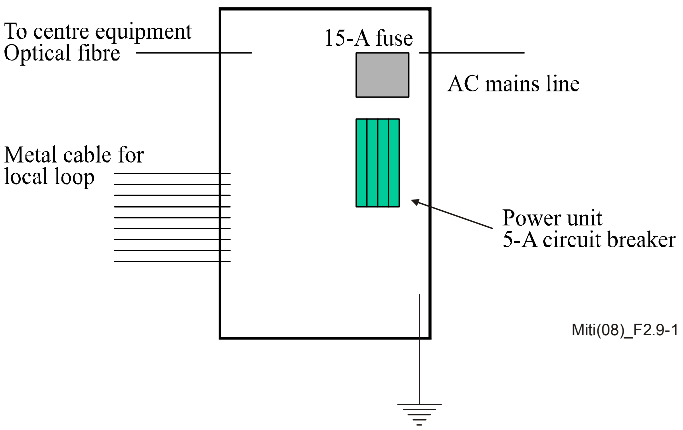


Figure 2.9-1 – Access network system

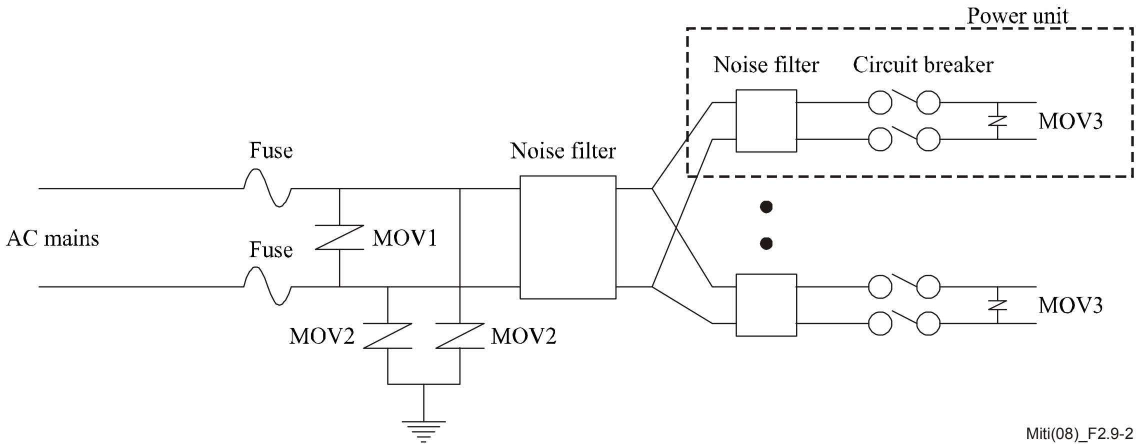


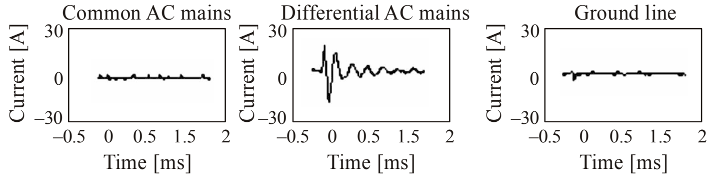
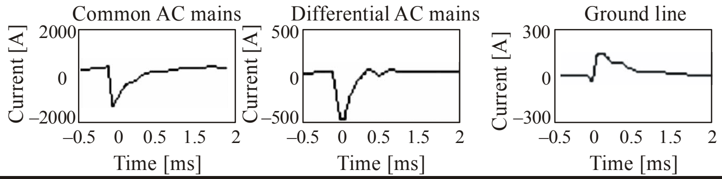
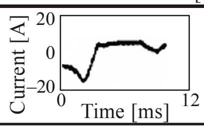
Figure 2.9-2 – Structure of overvoltage and overcurrent protection

Measurement/Experiment

1) Observation

The lightning surge currents in common mode and differential mode were observed in ten systems where failure often occurred. Two types of waveform and occurrence probability were obtained. The data are summarized in Table 2.9-1 and Figure 2.9-3. Malfunctions occurred with both waveforms. The peak current values were about 30 and 300 A, respectively.

Table 2.9-1 – Observed waveforms

Type of waveform		Characteristics of waveform
Lightning About 300 sets	Only differential mode appeared 77%	
23%	Common and differential and ground appeared	
Other About 1200 sets	Only differential appeared	Peak current was 20 A. And the half-time value was from several milliseconds to several tens of milliseconds. 

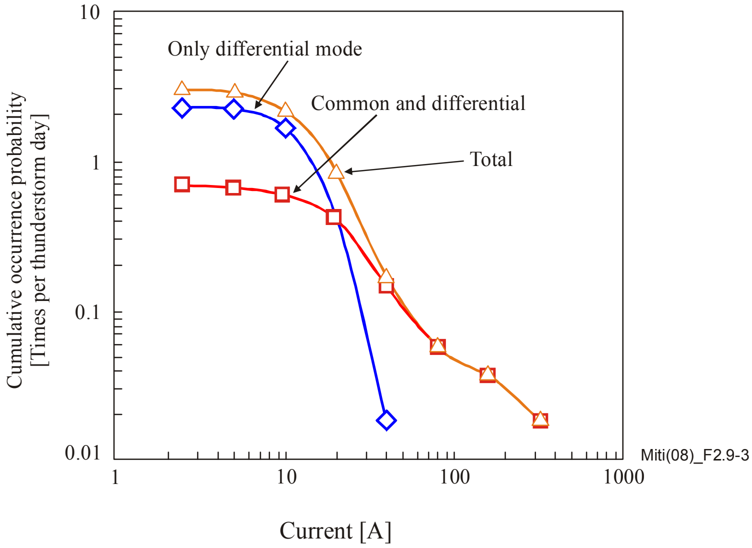


Figure 2.9-3 – Cumulative occurrence probability for differential mode current

2) Experiment

Noise immunity and lightning surge were tested. Malfunction did not occur in the immunity test. Also, several lightning surge generators (e.g., 10/700 ITU-T and 1.2/50 combination) and coupling/decoupling methods were tested (Figure 2.9-4). It was necessary to test the coupling and decoupling units to confirm the induced waveform and current value, which depended on them (Figure 2.9-5). The results are shown in Figure 2.9-6.

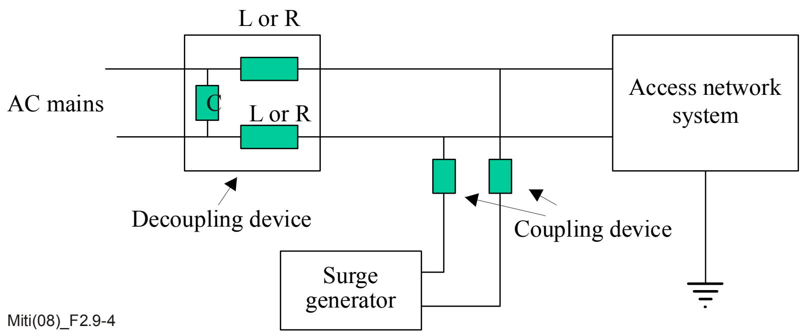


Figure 2.9-4 – Example of experimental set-up

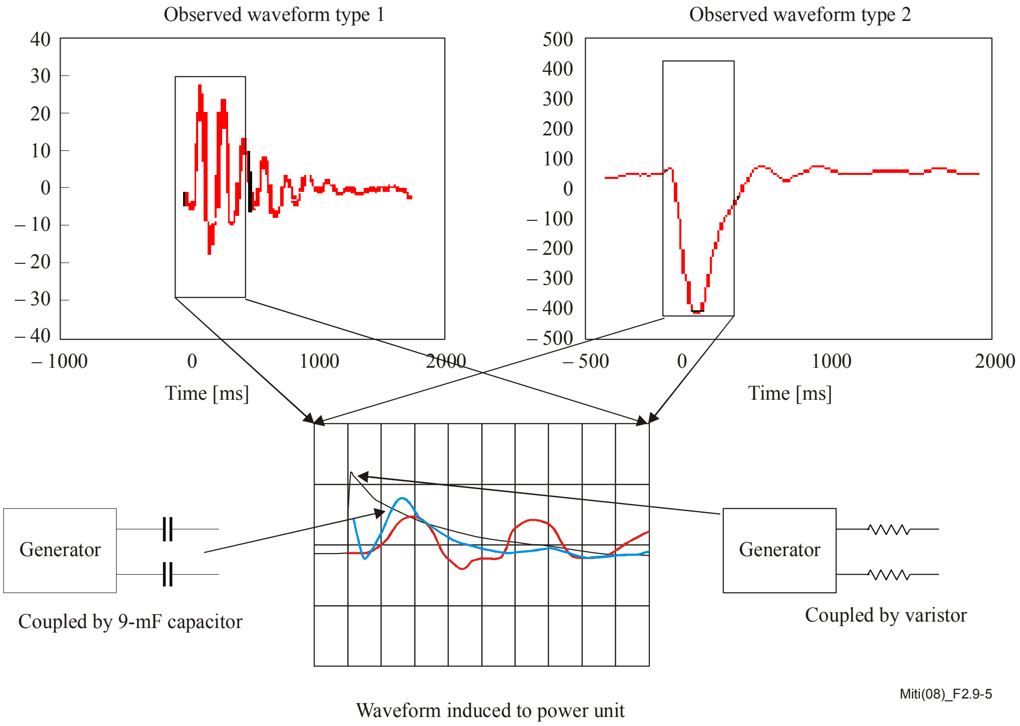


Figure 2.9-5 – Waveform difference by coupling methods

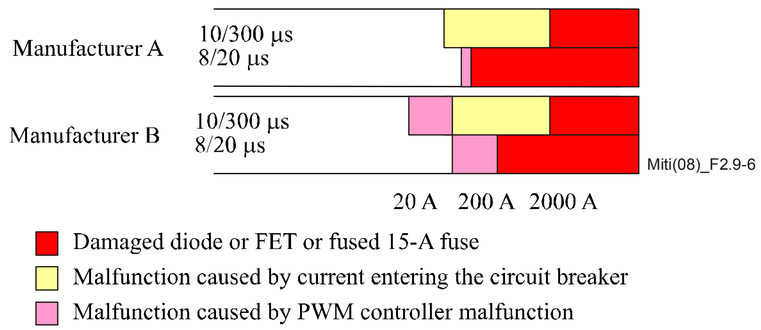
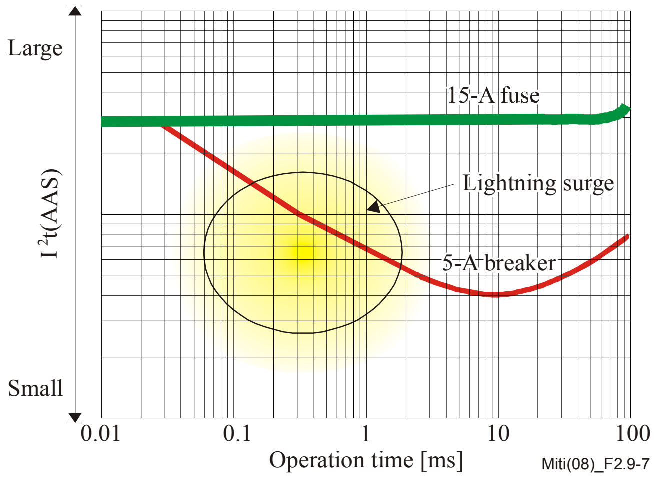
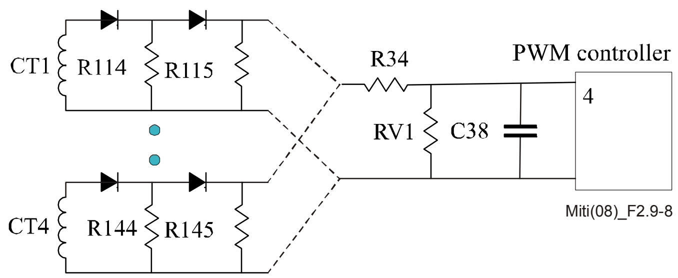


Figure 2.9-6 – Experimental results

Mitigation method
This malfunction was caused by two mechanisms. One was the lightning surge current flowing into the circuit breaker when MOV3 operated. In the field, the 15-A fuse did not break often, but the breaker did trip. The relationship between the lightning and operation time is shown in Figure 2.9-7. A new circuit breaker, whose characteristics at the AC mains frequency were the same, was developed and the response characteristics to lightning were improved. The second mechanism was the malfunction of the pulse width modulator (PWM) controller, which has an overcurrent latch circuit consisting of a current transformer and filter circuits, as shown in Figure 2.9-8. The filter circuits (e.g., R114, R115, R34, RV1, C38) were from different manufacturers. In particular, R114 and R144 determine the sensitivity of CT1 and CT4, so their resistances were set smaller, and this improved the immunity level against lightning surges.    **Figure 2.9-7 – Operation time and energy**    **Figure 2.9-8 – PWM controller and filter**