Case study # 2.10

Title Protection of a wireless service connected to a few kilometres of copper cable

Type of trouble Damage.

Source of trouble Lightning.

System affected Access switch.

Location Outdoors (On a pole in a rural area).

Keywords Damage, lightning surge, protection coordination, GDT, solid state overcurrent protection.

Version date 2004-01-01

System configuration

The antenna and the electronics containing the subscriber line interface circuit (SLIC) of a wireless service are normally mounted on the side of the customer's house or on a pole within a few metres of the house. In some installations, where the house is not in line of sight with the radio base station, the antenna and electronics may be installed a few kilometres from the house. When this type of installation is used in a lightning-prone area, lightning protection is installed to protect the electronics.

In this case, although gas discharge tubes (GDTs), and in some installations GDTs plus positive temperature coefficient (PTC) type overcurrent protection, were installed, lightning damage still occurred regularly (see Figure 2.10-1).

Figure 2.10-1 – Original system configuration
Introduction

Damage was first identified in a couple of surface mounted diodes, see Figure 2.10-2 below, which are near the switch mode power supply connector.

![Figure 2.10-2 – Picture of damaged diode](image)

Circuits, schematics and printed circuit board (PCB) layouts were obtained for this part of the system. This information, in combination with installation documentation, enabled a scenario for damage to be determined. It also identified components likely to be damaged. These components were:

- a thyristor protection circuit, which is a switching type protector and the first component on the printed circuit board where the line terminates;
- a diode which clamps the incoming line to the –70 V supply rail (line);
- a diode which clamps the incoming line to the –35 V rail (line);
- two diodes which connect from the –35 V and –70 V supply lines to the SLIC circuit. One of these diodes is shown damaged in Figure 2.10-2 above;
- the SLIC circuit.
Investigation

The scenario is that a negative surge exceeding –70 V will drive the –70 V supply more negative due to current being conducted via the diode which clamps the incoming line to the –70 V supply rail. If the –70 V rail becomes too negative, it can cause semiconductor "latch up" of the SLIC. "Latch up" is a failure mechanism in semiconductor devices where externally applied transients exceeding the maximum supply voltage result in the triggering of internal parasitic transistors forming a thyristor-type structure. This internal thyristor can conduct appreciable current and typically results in the rapid destruction of the device.

The network operator investigated damage to the external thyristor protection circuit, to the diode which clamps the incoming line to the –70 V supply rail, and to the SLIC, by electrically characterizing these components and then de-encapsulating those components with degraded characteristics and inspecting them under an optical microscope. The SLIC showed signs of significant damage consistent with "latch up" indicating that the power supply was supplying current conducted to ground via the SLIC. The thyristor protection circuit had no signs of damage.

Surges were applied to a working circuit to verify this scenario. Figure 2.10-3 shows negative surges applied to an unprotected circuit. The generator surge (–191 V) causes a surge of –100 V on the b leg of the circuit. The difference of 91 V is due to the voltage drop on the coupling metal oxide varistor (MOV). The surge has caused the –70 V rail to be driven more negative (–70 V to –96 V). After a few surges, permanent damage has occurred.

![Figure 2.10-3 – Waveforms during a damaging surge](image)
The failure appears to be caused by a negative surge entering under the firing voltage of the thyristor protection circuit (±190 V) and causing the –70 V and the –35 V rails to become more negative by the current entering the power supply via the diode which clamps the incoming line to the –70 V supply rail. When the –70 V rail is surged to approximately –100 V and the –35 V rail is surged to approximately –45 V, the SLIC latches up and the current is conducted from the –70 V and –35 V rails to ground, see Figure 2.10-4, which shows the current path through the thyristor protection circuit and the diode to –70 V, and the current from the –70 V and –35 V rails through the SLIC. It is the power supply current that damages the two diodes which connect from the –35 V and –70 V supply lines to the SLIC circuit (based on the fact that the diode which clamps the incoming line to the –70 V supply rail is not damaged).

The diode which clamps the incoming line to the –70 V supply rail was probably added to prevent the SLIC line inputs exceeding –70 V. However, adding this diode has resulted in rendering the thyristor protection circuit redundant and causing the SLIC to have its –70 V and –35 V ratings exceeded.

The scenario was confirmed by applying surges to a working circuit.

**Figure 2.10-4 – Simple circuit showing path of surge on tip side of line**

Magnitude of Voltage V less than required to operate either the thyristor protection circuit or the GDT. Only part of the Tip side of the circuit is shown for simplicity.
As the equipment is being damaged by lightning surges of 10s of amperes, a fast acting overcurrent protector is required. A possible solution is to install a recently developed semiconductor overcurrent protector (SOP) (see Appendix II of ITU-T K.30 for details of this type of device) between the electronics and the GDT. This will limit the current entering the power supply to approximately 200 mA and prevent the –70 V and –35 V rails from being driven more negative. There may be other solutions, but they would involve a change to the circuit design or development of a custom external protector. This is unnecessary as a suitable device is available to fix the problem.

Tests were performed on a working circuit in the test laboratory to check if the SOP device will protect the electronics. Figure 2.10-5 is a surge below the operating voltage of the GDT (–226 V at the GDT). The maximum voltage across the overcurrent protector is 158 V (226 V – 68 V). A negative surge pulls the b leg negatively until the diode connected to –70 V begins to conduct. As soon as the current through the SOP exceeds 200 mA, it operates and goes into a high resistance state. If the surge voltage is high enough, the GDT operates and protects the SOP.

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Figure 2.10-5 – Waveforms showing the semiconductor overcurrent protector blocking the surge
Tests performed indicate that the SOP will protect the circuit. Because the SOP limits the current to 200 mA, it prevents both the –35 V and the –70 V power supply voltages from being forced negatively. Figure 2.10-6 shows the new circuit configuration.

A field trial, where one of the two circuits was protected by a GDT and the SOP, has proved the success of the proposed protection. Within a few weeks of the installation, a lightning storm damaged the circuit protected by a GDT whereas the one protected by the combination of a GDT and the SOP continued to operate.

Figure 2.10-6 – GDT and SOP protected system

References

Rec. ITU-T K.30