# Performing GR-1089-Core Lightning and Power Cross Test

**A review of the test methodologies and equipment required to perform GR-1089-CORE lightning and power cross testing.**

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## ABSTRACT

The pitfalls and difficulties in performing testing in accordance with GR-1089-CORE, Section 4 are discussed. A brief description of the GR-1089-CORE document is presented to familiarize the reader with the importance of this requirement. The paper hopes to stimulate the reader into further discussions on the test methodologies of GR-1089-CORE. A description of the types of equipment that are typically required to meet the Lightning and Power Fault test is provided.

## INTRODUCTION

With the recent upswing in the use of the Internet, the need for faster and more reliable routers, servers, and switches capable of handling traffic from various broadband sources such as Digital Subscriber Lines (DSL), ISDN, T1, fiber, and plain old telephone service (POTS) has grown tremendously. As a result of this growth, the Regional Bell Operating Companies (RBOC) and other service providers are attempting to bring new devices online at a rapid pace. These devices are expected to meet the requirements of GR-63-CORE (environmental requirements) and GR-1089-CORE (electrical requirements). These two documents are known as the Network Equipment Building Systems (NEBS) requirements and are designed to assure the safe and efficient operation of the Network in a wide range of harsh environments. Other requirements such as GR-499 and RBOC specific documents are imposed in addition to GR-63-CORE and GR-1089-CORE. Tests include some rather benign requirements such as package vibration and drop test. Other tests are quite severe such as seismic, fire, operating humidity, ESD, lightning, and power fault (power cross). This paper will concentrate on the lightning and power cross test. However, it is important to keep in mind that the other requirements could be affected by the outcome of any of the tests. For instance, a system may fail lightning or EMC and thus require a larger filter on the power input. The filter allows the system to comply with EMC but the added weight could cause a change in the center of gravity, which, in turn, would cause a noncompliance during the seismic test. If the components in the filter might not be fire rated and could add to the fuel load, they may cause a failure during the fire test. In order to meet all NEBS requirement, a large database of knowledge and experience is required by the test engineers and technicians.

## CALIBRATION OF GENERATORS

The most unique aspect of GR-1089 test is the calibration or characterization of the test generators. This aspect is a direct result of the differential nature of the telecommunication connection (tip and ring). A five terminal generator (T, R, T1, R1, Rtn.) is required for common-mode test. For standard POTS, a three terminal generator (T, R, Rtn.) will be sufficient. Both the open circuit voltage (OCV) and short circuit current (SCC) requirements, as well as the waveshape, must be met. This requires that the OCV must appear on all outputs simultaneously. Then, the OCV must appear on all the outputs except for one, which is shorted; and that one output have met the SCC. Then two outputs are shorted, and the OCV and SCC are again measured. This process continues until all the outputs are shorted, and they all must meet the SCC requirement. Obviously, calibration of the generators can be a time-consuming task.

The initial reaction when designing such a generator is that maintaining the waveshapes for OCV and SCC are almost impossible. However, the rise time and duration as defined in ANSI C62.41 (rise time is 1.25 times 10 to 90% and duration is first 10% to second 50% points) are maximums and minimums. That is, faster rise times are allowed and slower durations are allowed. This helps the pulse designer to meet the OCV and SCC requirements. The problem arises when the design is such that the duration on the OCV is so large as to over test the equipment-under-test. This would occur if the designer were having difficulty meeting the SCC duration and solved the problem by having a very long OCV duration (2 or 3 times the requirement). Of course, these problems do not exist for the power cross test which is defined as a 60-Hz waveform with a RMS voltage and current value. The values are obtained by using the proper source impedance for the generator. The difficulty here is finding good power resistors and building a safe generator.

## TEST PHILOSOPHY

The equipment-under-test is required to meet two test criteria. The first level criteria require normal operation after the test surge without damage. The second level criteria require that the unit not become a fire, fragmentation or electrical hazard. This second level criteria is confirmed through the use of a witness cloth consisting of bleached, untreated cheesecloth. The cloth is wrapped around the circuit pack, shelf, rack, or magazine under test. Any indication of ignition, charring, or ejection of materials is to be considered a failure. Any conditions indicating a violation of the safe operation of the system will also be considered a failure. These criteria hold for both the lightning and power cross test.

Both the lightning and the power cross tests are applied to the telecommunication ports only. The dc power line is assumed to be protected internally at the power source. Commercial ac power is usually not utilized in a central office environment but is required to meet EN61000-4-5 lightning test. Data or I/O lines are considered to be intra-building leads and very short compared to telecom lines. They are also exempt from the test. Intra-building telecom lines are required to meet a less severe test requirement not discussed. The test levels are based upon the assumption that the facility is protected by a voltage-limiting device with an approximate breakdown voltage of 1000 V differential.

The power cross requirement is derived from the possible condition that an electrical power line comes in contact with the telecommunication line. If the fault occurs on a primary power line, the fault will be cleared quickly (less than 5 seconds) and the voltage-limiting protector will limit voltages to 600 V rms. If the fault occurs on a secondary line, the condition may persist for a long time until cleared by the power company. Here the voltage (110–277 V) is below the voltage-limiting protector and will not be reduced in any manner.

Further details on the data used to establish these levels are found in TR-EOP-000001.

| Surge # | Voltage (V) | Current (A) | Rise/Duration (μsec) | Repetitions | Connection |
|---|---|---|---|---|---|
| 1 | ± 600 | 100 | 10/1000 | 25 | differential |
| 2 | ± 1000 | 100 | 10/360 | 25 | differential |
| 3 | ± 1000 | 100 | 10/1000 | 25 | differential |
| 4 | ± 2500 | 500 | 2/10 | 10 | common |
| 5 | ± 1000 | 25 | 10/360 | 5 | common |

*Table 1. First level lightning surge.*

| Surge # | Voltage (V) | Current (A) | Rise/Duration (µsec) | Repetitions | Connection |
|---|---|---|---|---|---|
| 1 | ± 5000 | 500 | 2/10 | 1 | common |

*Table 2. Second level lightning surge.*

## LIGHTNING REQUIREMENT

The first-level (operational) lightning requirement is summarized in Table 1. Not all five tests are required. Surge 3 may be performed in place of 1 and 2. Therefore, the requirement consists of surges 1, 2, 4, and 5 or 3, 4, and 5. The latter test sequence is the most efficient. Test surges 1, 2, 3, and 5 represent the 1000 V differential let-through voltage of the protector. Test surge 4 represents coupling to the grounding conductors and thus bypassing the protector. This coupling would appear as a common mode voltage.

For test connection, differential applies between all combinations (T with all other grounded, T & R with all other grounded, etc.) and common applies to all leads simultaneously. All the calibrations must be performed prior to test verifying the OCV and SCC of each combination. Waveform 5 is a special case where up to 12 tip-and–ring pairs are tested simultaneously. If the unit contains less than 12 pairs, then all pairs are tested. Note that the same calibration procedure needs to be followed as described above (*i.e.*, all OCV and SCC combinations of each pair with the other pairs opened and short-circuited). If the unit contains more than 12 pairs, the pairs to be tested are to be chosen such that the distribution is as even as possible across the available pairs. If the unit has multiple power distributions, then another test(s) is required on a 12 pair set that share a common power fuse. As can be seen, testing only a few telecommunication pairs could easily be a four to five day effort.

The second level lightning surge (fire, fragmentation, or safety) is summarized in Table 2. This waveform simulates a nearby strike coupling into the grounding conductors.

## AC POWER FAULT REQUIREMENT

The first level (operational) ac power fault tests are summarized in Table 3. All tests are performed at 60 Hz. If the unit has a primary protection device such as a heat coil, these devices are to be removed for all tests except for test number 4. Additional tests are discussed in GR-1089, but are established as objectives and not requirements. Since these additional tests are less severe than the second level tests, most customers attempt to meet the first level objectives during the second level test. In addition, if the unit contains a voltage or current limiting device such as a gas tube, then an additional test is required to assure that the device will not trigger due to low level induced currents. The test in Table 3 will also need to be performed at just below the triggering threshold of the voltage or current limiting device.

The second level (fire, fragmentation, or safety) ac power fault test is summarized in Table 4. All tests are performed at 60 Hz. If the unit has a primary protection device such as a heat coil, these devices are to be removed for all tests. If the unit contains a voltage or current limiting device such as a gas tube, then an additional test is required to assure that the device will not trigger due to low level induced currents. The tests in Table 4 will also need to be performed at just below the triggering threshold of the voltage or current limiting device. Some of these tests are required for safety testing to UL 1950 and need not be repeated if testing has been performed by a National Recognized Testing Laboratory (NRTL). Test number 4 is to be performed at any voltage between 100 and 600 V that causes worse case fire hazard conditions.

## TEST CONDITIONS AND SAFETY

As can be concluded from the above discussion, the lightning and ac power fault tests can produce lethal voltages. The test generators used to produce the lightning waveforms are on the order of 100 µF with voltages up to 10 kV. The energy is approximately 5000 J. This is enough energy to give someone a good jolt and must be respected. The ac power fault test will definitely kill if these voltages came in

| Test | Voltage (Vrms) | Current (Arms) | Duration | Connection |
|---|---|---|---|---|
| 1 | 50 | 0.33 | 15 minutes | differential |
| 2 | 100 | 0.17 | 15 minutes | differential |
| 3 | 200, 400, & 600 | 0.3, 0.7, & 1.0 | 60 x 1 second | differential |
| 4 | 1000 | 1 | 60 x 1 second | common |

*Table 3. First level ac power fault.*

| Test | Reason | Voltage (Vrms) | Current (Arms) | Duration | Connection |
|---|---|---|---|---|---|
| 1 | Secondary contact | 120, 277 | 25 | 15 minutes | differential |
| 2 | Primary contact | 600 | 60 | 5 seconds | differential |
| 3 | Short term fault induction | 600 | 7 | 5 seconds | differential |
| 4 | Long term fault induction | 100-600 | 0.37-2.2 | 15 minutes | differential |

*Table 4. Second level AC power fault.*

contact with a person. These tests are performed in a controlled area with a trained person present at all times. The ac power fault test requires power feeds directly from the main power source so the disconnects and controls to this test device are locked and tagged out. Since the witness cloth may ignite, a fire extinguisher is nearby at all times. A method of evacuating the atmosphere in the area quickly is also required since the smoke may be toxic.

The typical lightning protection design employs a fast switch to divert all energy to ground prior to entering the equipment. This requires placement of a TranZorb, MOV, or diodes either on the board directly behind the connector or inside the connector. These devices must be rated to react within the time frame of the rise time, must have the capability to handle the duration (energy flow), and must not disrupt traffic flow during non-transient events.

The typical ac power fault protection design employs the use of fuses to protect the system from the second level faults. The simplest design uses total isolation so no current will flow when 1000 V is placed between tip or ring and ground. Fuses may still be supplied as a secondary protection in case a low impedance is caused by the preceding tests.

## CONCLUSION

Meeting GR-1089-CORE test requirements can be a very challenging task. Combined with the GR-63-CORE requirements, the compliance engineer can be faced with an endless loop of changes for each test. Working with a team of people (no one person is a NEBS expert) experienced with all the NEBS testing will direct the compliance engineer to a cost-effective and timely design solution.

## REFERENCES


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