Inter-system Ground Noise: Causes and Effects

White Paper 8

Revision 2

by Neil Rasmussen

> Executive summary

Many power-related problems are the result of inter-system ground noise. This problem cannot be corrected using typical AC-only power protection equipment. The cause and solution of inter-system ground noise problems are described.

Contents

Click on a section to jump to it

APC white papers are now part of the Schneider Electric white paper library produced by Schneider Electric's **Data Center Science Center**
DCSC@Schneider-Electric.com

Schneider Electric

Introduction

An Uninterruptible Power Supply (UPS) system is an essential part of a business computer system, but it cannot completely protect the computer from all power related problems. In working with installers of business computer systems over time, Schneider Electric has identified installation configurations, which have special risks. Most computer power protection equipment is designed to protect the load or loads, which are attached. In the ideal case, no connection point to the computer exists except for the AC power cord. This allows the power protection equipment complete control over noise or transient voltage events that could enter the computer from the outside world.

In the real world, computers are more often than not interconnected to other remote devices via network wiring, printer data lines, and modem telephone lines. AC power protection equipment cannot stop transients from entering the computer via these data connections. In fact, these connections may allow a dangerous and common type of AC power problem to damage hardware or stored data. The problem is inter-system ground noise and it cannot be corrected using typical AC-only power protection equipment.

Safety grounding

All computer equipment is equipped with three wire grounding type AC power connectors. Many types of equipment, such as lamps, have only two wire type plugs since two wires are all that is necessary to deliver AC power. The third wire is a safety ground wire, which is connected to all exposed exterior metal parts on the computer equipment. The grounding connection provided at the wall receptacle is connected within the building to copper water pipes and/or structural metal parts of the building. The purpose of this arrangement is to protect the user from electrical shock when the exposed metal parts of a faulty computer and building structural metal parts are touched. For safety, exposed devices such as RS-232 connectors and printer ports are considered to be exposed metal parts. For this reason, the voltage at any connector pin must be ground, or present a small voltage with respect to ground. The result is that in virtually all computer equipment, the CPU common wire or ground reference is connected to the safety grounding wire (and the enclosure) of the equipment.

In a system including equipment that is interconnected via data lines, the safety grounding arrangement leads to a conflict. Every interconnected device has two connections, which are attempting to establish the common reference voltage for data communications: 1) the common wire in the data line, which connects the device to other equipment, and 2) the device's safety grounding wire. This situation is sometimes known as a “ground loop”. In the next section it will be shown how the existence of this loop can lead to differences between the common reference voltage between any interconnected devices, which can be damaging to hardware and data. These ground voltage differences between interconnected devices must not be confused with other power problems such as common mode noise, normal mode noise, EMI, or RFI. These ground voltage differences are referred to as inter-system ground noise.

Inter-system ground noise is not the same as common mode noise

One of the most widespread misunderstandings in the field of computer power protection is the difference between Inter-system ground noise and common mode noise. Common mode noise is defined as noise that exists between the power conductors, hot and neutral, with respect to the ground conductor. Inter-system ground noise exists between the ground wires supplying interconnected computers. Free standing computers which are not connected via any data lines cannot experience inter-system ground noise. It is possible for a computer to experience severe common mode noise, while experiencing no inter-system ground noise, and vice-versa. These two problems are completely independent.

A key reason why there is so much confusion in this area stems from the fact that power protection equipment can reduce common mode noise but cannot help correct inter-system ground noise. Power protection manufacturers, in fact, have an interest in leading users to believe that inter-system ground noise is equivalent to common mode noise because they make products that correct common mode noise. The literature and popular thinking on this subject mistakenly emphasize common mode noise while ignoring inter-system ground noise because sales and technical literature from power protection manufacturers are the leading sources of information on these subjects.

Sources and effects of inter-system ground noise

A simplified diagram of an ideal interconnected system is shown in **Figure 1**. The grounding wires from all of the interconnected equipment come from the same source, ensuring that they start out having the same voltage. No current of any kind flows in any of the ground wires, and they are not subject to any magnetic fields. This ensures that there can be no voltage drop along the ground wires. The result is that all points along all of the ground wires are at the same voltage and that there is no inter-system ground noise between devices attached at various points along the grounding system. The oscillographs in **Figure 1** show no current noise.

Unfortunately, significant effects prevent realization of the preceding ideal scenario. In some cases, the deviation from the ideal can result in data corruption and even hardware damage. An interconnected system experiencing inter-system ground noise is shown in **Figure 2**. In the figure, interconnected systems are subject to different ground noise voltages, giving rise to ground noise current in the data line which connects the two systems. The offending ground noise in this case results from noise current injected into the ground system of one of the computers by "other equipment." Inter-system ground noise can result from a variety of different problems, which are explained as follows:

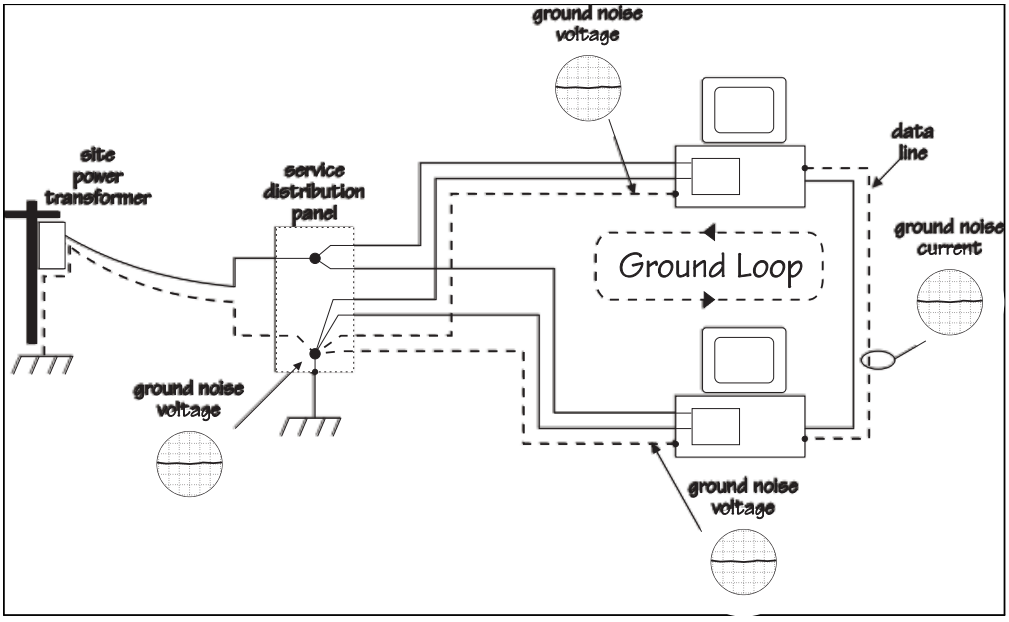

Figure 1

An ideal interconnected system

Ground noise injection

Although the safety ground wire is intended for grounding of the equipment enclosure, all computer equipment uses this wire for another purpose - to provide a reference point to filter out unwanted emissions of radio frequency interference from the computer equipment. Common and normal mode electrical noise on the power line is injected into the ground line by the filter present in the power supply of each computer and workstation. Improperly designed surge suppressors may contribute to this problem. Effect: This injected noise current gives rise to a noise voltage between the common references of the interconnected equipment. Because the noise voltages usually become larger when the distance between the equipment is increased, data transmissions can become compromised in some situations.

Ground faults

If the interconnected devices are on different electrical circuits in the building and one of these circuits is shared by some other unrelated equipment, which has an insulation failure, then before the circuit breaker trips, a very large fault current will be injected into the safety ground wire. This will give rise to a momentary ground voltage surge at the computer equipment that is supplied by the circuit breaker, which is tripping. The size of this voltage surge may be from a few Volts to over one-half of the rated power voltage (either 120 VAC or 230 VAC), depending on the quality of the grounding system. Effect: This will result in a voltage difference between the common reference points of the interconnected equipment that can easily exceed the data signal safety voltage rating. Destruction of input/output drivers and CPU motherboards can result.

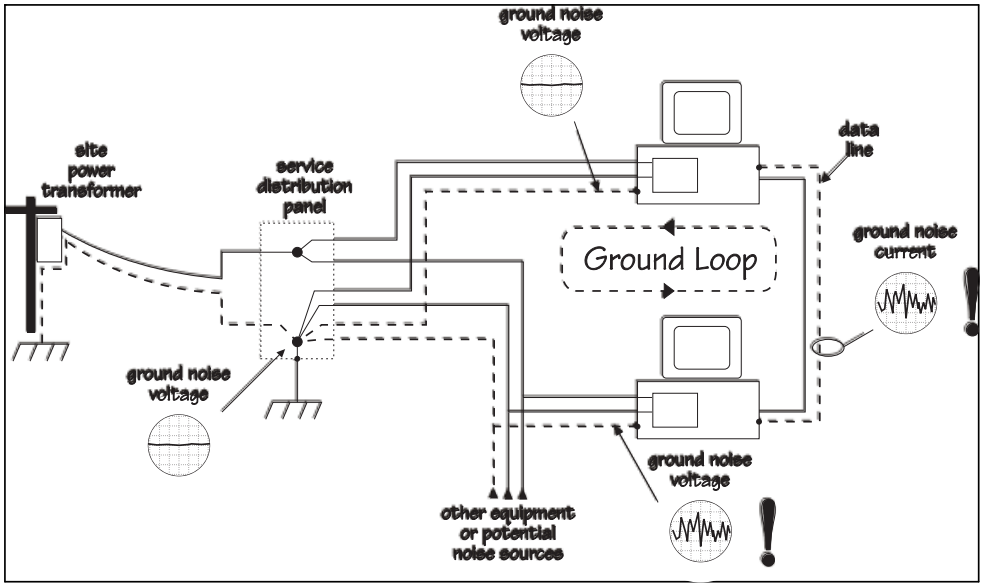

Figure 2

A practical interconnected system

Ground currents

This is the most common problem identified. If the pieces of interconnected equipment are supplied by different electrical sub-panels (circuit breaker boxes) in the same or different buildings, then many problems can cause the ground voltage supplied to the interconnected devices to be different. Depending on local or national electrical codes, many different wiring systems are possible between separate sub-panels. Most of these inter-panel wiring systems do not guarantee that the ground voltages supplied by the sub-panels will be equal. In many cases the inter-panel ground connections are themselves part of other ground loops (such as building frame members) unrelated to the ground loops caused by the device data connection. A large number of situations can give rise to dangerous ground voltage differences between sub-panels including nearby lightning strikes to ground, lightning induced currents in

ground loops external to the ground loop caused by device data connections, poor building grounding (sandy soil), fault currents (breaker tripping) in apparently unrelated buildings or circuits, or nearby electrical repair work. Effect: This will result in a voltage difference between the common reference points between devices, which can easily exceed the data cable safety voltage rating. Destruction of data interface drivers and CPU motherboards can result. Another common side effect is heating of the data cabling (cable becomes warm or hot to the touch).

Lightning induced voltage

This is a common and damaging form of ground voltage noise. In this case, the ground loop acts as an antenna. Nearby lightning strikes create enormous electromagnetic pulse noise, which is received by the antenna. A large circulating current in the ground loop can be created. Effect: This current may cause the voltage difference between the common reference points on interconnected devices to exceed the safety voltage rating. Damage to the data interface driver cards is common, and propagation of the damage into the CPU motherboard is possible. The area of the ground loop controls the magnitude of the problem. In rare circumstances, other types of equipment may create electromagnetic pulses, which are picked up by the ground loop (such as NMR/MRI imaging machines).

Breaking ground loops by cutting wires

It may be apparent that the source of all of these problems is the ground loop caused by the electrical safety ground. In many cases, disconnection of this ground at one piece of equipment may prevent problems. However, ground wire disconnection should never be performed because it is illegal and presents a severe shock hazard. It is sometimes suggested that an isolation transformer might be used to solve the ground loop problem. This will not work because all safety agencies require that the ground wire of an isolation transformer be passed through between the input and output (only the power wiring may be isolated).

Some equipment is relatively immune to inter-system ground noise

Some network wiring is completely isolated and does not create ground loops when used to interconnect equipment. In this case, inter-system ground noise voltages can exist, but will have no effect. Examples of such immune network wiring are Ethernet and fiber-optic cables.

Related resource
White Paper 16
Protection of RS-232 Serial Connections

Some equipment is very vulnerable to inter-system ground noise

Examples of interconnections which are subject to inter-system ground noise are RS-232 data links, long printer data wiring, USB wiring, and network AUI wiring. For the proper procedures needed to prevent problems when using RS-232 connections consult White Paper 16, *Protection of RS-232 Serial Connections*. This White Paper also includes suggestions of power wiring practices, which can reduce inter-system ground noise. To understand the effects of power problems on network wiring, consult White Paper 9, *Common Mode Susceptibility of Computers*.

Related resource
White Paper 9
Common Mode Susceptibility of Computers

Conclusion

Inter-system ground noise is a type of power problem that is not widely understood but can result in mis-operation or even destruction of equipment. The widespread use of Ethernet and optic fiber network connections, which are electrically isolated, has decreased the problem over time. However, non-isolated equipment connections such as RS-232, parallel, and USB can give rise to situations where inter-system ground noise poses a risk to equipment operation. Such connections should be kept short and the interconnected equipment should be powered from the same branch circuit.

About the author

Neil Rasmussen is a Senior VP of Innovation for Schneider Electric. He establishes the technology direction for the world's largest R&D budget devoted to power, cooling, and rack infrastructure for critical networks.

Neil holds 19 patents related to high-efficiency and high-density data center power and cooling infrastructure, and has published over 50 white papers related to power and cooling systems, many published in more than 10 languages, most recently with a focus on the improvement of energy efficiency. He is an internationally recognized keynote speaker on the subject of high-efficiency data centers. Neil is currently working to advance the science of high-efficiency, high-density, scalable data center infrastructure solutions and is a principal architect of the APC InfraStruXure system.

Prior to founding APC in 1981, Neil received his bachelors and masters degrees from MIT in electrical engineering, where he did his thesis on the analysis of a 200MW power supply for a tokamak fusion reactor. From 1979 to 1981 he worked at MIT Lincoln Laboratories on flywheel energy storage systems and solar electric power systems.

Resources

Click on icon to link to resource

Protection of RS-232 Serial Connections
White Paper 16

Common Mode Susceptibility of Computers
White Paper 9

White Paper Library
whitepapers.apc.com

TradeOff Tools™
tools.apc.com

Contact us

For feedback and comments about the content of this white paper:

Data Center Science Center
DCSC@Schneider-Electric.com

If you are a customer and have questions specific to your data center project:

Contact your **Schneider Electric** representative