Risk Mitigation for Telephone Operators and Technicians

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Abstract

There is a growing concern that telephone operators and equipment technicians may be at lethal risk in certain lightning-related situations. The producers of electronic switching systems have espoused isolated ground planes for their systems for the past twenty years. This isolated, or single point, ground system is considered synonymous with reliability because they result in fewer circuit failures during atmospheric disturbances.

One problem with this technology is the fact that building steel is a relatively low impedance path to ground, whereas the office vertical equalizer is very high by comparison. If the building steel (integrated ground plane) takes a direct lightning stroke, it is several microseconds before the resultant ground potential rise travels to the office principal ground point and then up the vertical equalizer to the isolated plane. For that period of time the two planes can be thousands of volts apart. In isolated ground offices, we see minor flashover burns in power cable insulation where the cables connected to the isolated ground plane arced to the cable tray in the integrated ground plane. The insulation on such cable is typically rated for 600 volts.

What about the human interface? Single-point grounding rules recognize that a person could come between the integrated and isolated ground planes, hence the well known six-foot (two meter) rule: Where the two ground planes are within six feet of each other, (thought to represent the span of the average man's arms) a bonding wire should be run to the ground window. This is intended to serve as an equalization path to protect the person. In the days of analogue ESS systems, this may have been adequate.

However, several questions come to mind. What purpose does the six-foot rule serve to people using twenty-foot headset cords? Another question regards technicians using video display terminals near the integrated ground plane. What is their risk?

The answer to both questions is that those people may be the connecting link between two ground planes which might be thousands of volts apart during the first moments of a lightning stroke. And, their risk serves no purpose. Equipment which is normally manned should be in the integrated ground plane. Thus, the human is at the same electrical potential as his environment during ground potential rises. There are very simple, and inexpensive technologies which would accomplish this.

With this paper, I intend to explore this potentially dangerous situation and offer several schemes to reduce or eliminate the risk to human life.

Background

Grounding is a subject which becomes more complex with the passage of time. Electro-mechanical switching systems were the world's mainstay through the middle 1960's. These technologies employed relays and other rugged elements in their design. As such, most lightning strokes were harmless beyond frightening an occasional technician. In addition to being inherently rugged, these switching systems were in the integrated ground plane. There were many interconnected paths for ground, and there was often current flow in the framework structures and the framework bonding and grounding conductors.

The first electronic switching systems, the Western Electric (AT&T) #1 ESS and the 101 ESS were designed for the integrated plane. Some years into the program a decision was made to use isolated grounding techniques, a product of bell Labs, for the #1 ESS. The reason: metal-oxide integrated circuitry was enjoying wide deployment in the network. And metal-oxide technology was very fragile.

Several documents and videotapes on isolated ground planes were presented by the late Messrs Robert (Bob) Beckley and Francis (Frank) Hubeny of Bell Telephone Laboratories. Most of the #1ESS machines of the day were retrofitted to isolated grounding and the later analogue machines, the #2, 2B and #3 ESS all used it.

As the world went digital, Western Electric included isolated grounding in their 4ESS product. The Bell Labs grounding designers were so concerned about 4ESS grounding, they included a current flow detector between the single point "Ground Window" and the integrated (C.O.) ground bar connection. It was thought that the detector would disclose unwanted ground "Loops" to the integrated plane.

Bellcore "bought into" isolated grounding, and published practice BR802-001-195. Principally, the '295 practice was the work of grounding expert, Mr. Paul Speranza (now retired) with input from S.M.E.s (Subject Matter Expert) working for numerous Bell Operating Companies, (BOC)s this author included. Mr. Speranza saw isolated grounding as a major factor in making switching machines more robust with respect to lightning hits.

Paul's premise was that a lightning stroke to the building steel would cause currents to flow towards ground, energizing the soil and rock strata around the building until it equalized. This equalization might be through the earth or skyward in the case of a return stroke. Regardless of how the energy dissipated, it's flow through the building causes a large magnetic field to build around the I beams, pipes, conduits and other conductors. The lines of force from this field would cut across the switching system inducing voltage, not unlike the action of a transformer.

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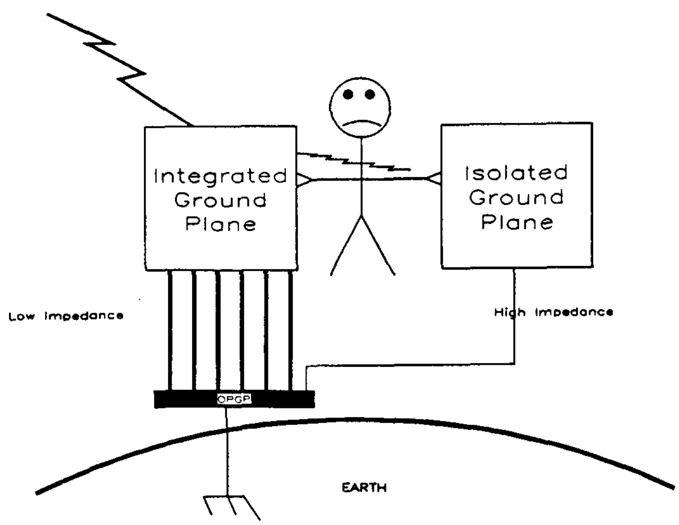
If more than one path to ground existed in the switching system, circulating currents could flow through the switching circuitry. The voltage drop across the switching system caused by these circulating currents could damage sensitive electronic microcircuits. A single point ground prevented this damage because no circulating currents could flow. A few switch vendors challenged Mr. Speranza's view of the flow mechanism, but it was generally agreed by all that the switching systems perform better in an isolated ground plane.

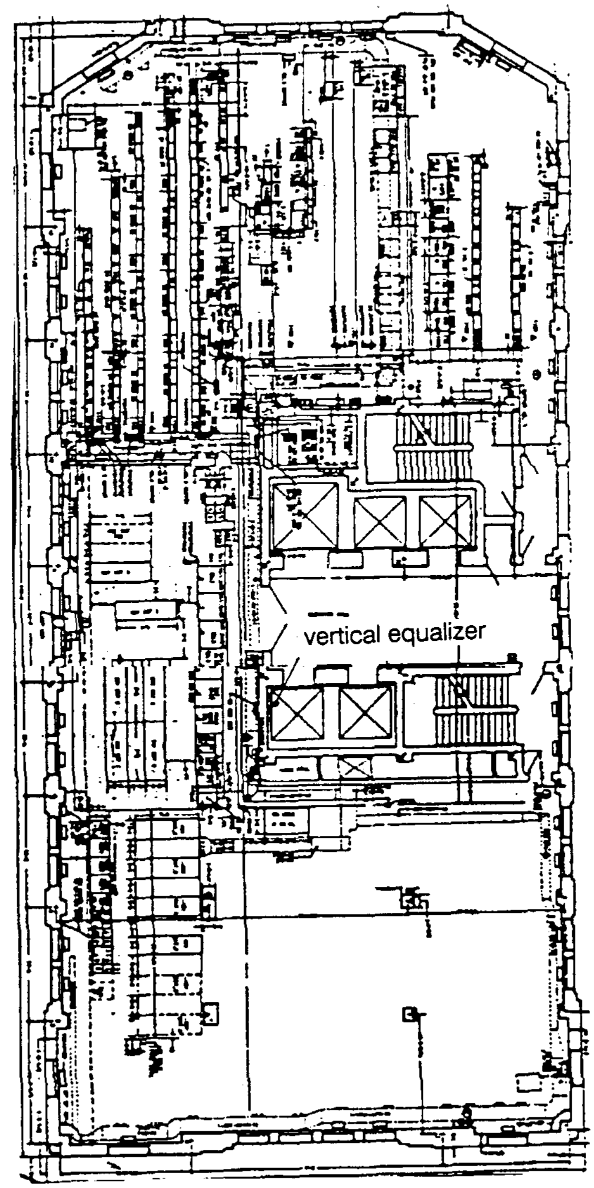
While that's fine for switching equipment, there may be substantial risk to technicians and operators unless their connection to the isolated ground plane (usually via terminals) is sufficiently removed from the integrated plane.

As it stands, isolated grounding is, perhaps a good method of protecting the switches, especially the analog ones. Analog switches were designed and built as a unit. The maintenance area and Input/Output (I/O) devices were part of the switching system. As such, they were well-defined on the floor plan, and generally, fell within the 6-foot (2-meter) rule.

About the only lightning related switch damage frequently encounter is minor insulation burning of power conductor in the cable racks. This is the result of "Flashover," which is encountered when the isolated ground plane (the ESS power cables) are at one potential and the integrated ground plane (cable rack) experiences a ground potential rise due to a lightning strike or a major ac power ground fault. These burns, though minor, offer dramatic evidence that the two ground planes were several thousand volts apart. Imagine being the operator or technician between those planes.



I believe the circuit looks like figure 2. It's a case study of a downtown Philadelphia Central Office serving approximately 150,000 lines and an equal number of private circuits. The building is approximately 260 feet (87 meters) tall and has approximately 38 I-beams serving as vertical columns. In addition, three busduct risers, and over a hundred assorted runs of conduits, water pipes, sewer lines, air ducts, cable racks, and auxiliary framing, all form what is lumped into the expression "Building steel."



The switching machines and their power plants are all referenced to a single 750 KCM copper cable run as a vertical equalizer through the building. This is illustrated in figure 3. There are formulas to calculate this, but it is intuitively obvious that the sheer mass of iron has many orders of magnitude less impedance to the RF component of the lightning stroke. The relatively puny 750 KCM would eventually be energized as the lightning's energy reached the basement and energized the Office Principal Ground Point (OPGP) busbar. Current would split at this point. Some would go to ground via the water-pipe connection, the driven rods, and the sheaths of the buried telephone cables.

Since the vertical equalizer and the switches are at a lower potential, the current will flow up the equalizer and eventually equalize the potential between the vertical equalizer and the integrated ground plane. This process will be assisted by the #6 AWG bonding equalizers normally run between integrated and isolated structures to satisfy the requirements of the six foot rule. By the time the currents are equalized, an injury or fatality could have occurred.

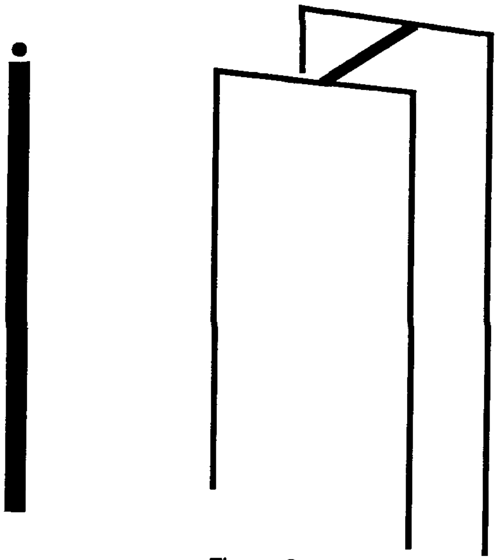


Figure 3
Vert. Equal VS Bldg Steel

Vertical Equalizer lags behind building steel ground potential rise.

Building steel takes lightning hit and "Sees" a ground potential rise.

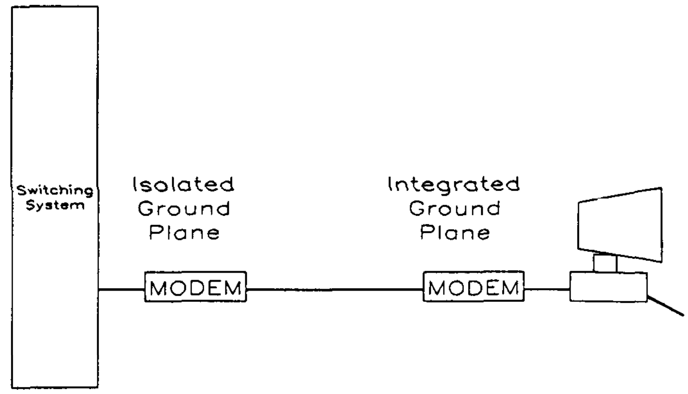
Modern digital switching systems use common Video Display Terminals (VDT) and/or Personal Computers (PC) as their I/O devices. These function in conjunction with printers and other devices, and are placed in a workstation environment virtually anywhere in the central office. Electrically, most of these are in the isolated ground plane. Often these are placed adjacent to other terminals and printers which are part of the integrated ground plane.

Operator service positions are increasingly designed around VDTs and PCs. Some vendors are insisting that these work in the isolated ground plane. I believe this is a serious mistake. While one can place the equipment on a permanent workstation and control that environment with some certainty, we can't control it all. Some operators and most supervisors use headsets equipped with long cords. These allow the person to walk about and, possibly, come into contact with the integrated ground plane through window frames, door bucks, conduits, thermostats, and metallic or metal-studded partition walls.

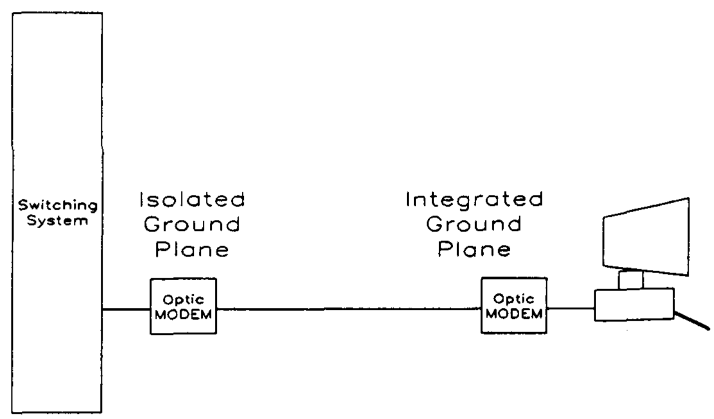
Cleaning personnel may use vacuum or carpet shampoo appliances right behind a working operator. Some operators and attendants may be working with radio, administrative, or other systems which are in the integrated ground plane.

Clearly, operators and technicians would be much safer if the equipment they connect their bodies to is at the same electrical potential as the building they occupy. Then, if lightning strikes, the whole structure, people included, rise with it.

How can this be achieved? Most I/O equipment, VDTs, PCs, etc. are connected to the switching system via serial ports, usually RS232C or similar. Pins 1 and 7 of an RS2323C are ground connections which carry through. If that ground path was interrupted, the terminal could be isolated from the switching system. There are MODEMs in the marketplace which offer a high degree of electrical isolation. Accordingly, if two MODEMs were installed, one at the terminal and one at the switching system, and a two-wire channel established between them, then the terminal could safely reside in the integrated ground plane.



Other means of accomplishing this are isolation type line drivers and fiber-optic systems. The fiber-optic systems employ device-powered drivers which convert the electrical data signals from the port to light which is carried over a photonic fiber and converted to electrical signals on the other end. This is similar to the MODEM approach.



Connected this way, I/O terminals or operator service positions could be located within the integrated ground plane to maximize the safety of the workers.

There is also a school of thought that holds there is no longer much reason to put switching systems in the isolated ground plane at all. While the original arguments of low logic voltage levels, high clock frequencies, and circuit fragility still hold, many other critical systems are functioning just fine in the integrated ground plane. And, they use the same kinds of electronics. Minicomputers are certainly a good example as are Digital Access Cross Connect Systems, multiplexers, and many other transmission and test systems. I believe modern techniques for circuit board layout, electrostatic shielding, and other physical design criteria could eliminate the need for the isolated ground plane. This would result in a safer, and probably less expensive to install system.

Conclusion

It does not make good business sense to expose people to needless risk. Lightning strikes our buildings fairly frequently, so the problem won't go away. The technology to render the system safe or safer exists today and is inexpensive. We need to change our approach to isolated ground planes.