Grounding Systems and Their Implementation

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Abstract

The isolated star ground system is the most popular implementation of technical grounding for the purposes of grounding sensitive electronic equipment. This approach has been in practice for many years, and while it is not a perfect solution, it is the solution that presents the least compromises. This paper documents the current approach as implemented in a number of large installations and is part of an on-going AES effort to document appropriate practices with regard to the control of noise in audio systems.

1. Introduction

The purpose of grounding is to provide safe, reliable and cost efficient power distribution. (Note that the cost element includes damage to the equipment due to a fault or lightning strike.) These are the goals of grounding from a power distribution viewpoint where electrical noise interference is not a consideration. In the case of sensitive electronic systems, such as audio, video and computer systems it is also necessary that the grounding system provide a stable and low impedance connection to earth to control electromagnetic interference (EMI). The isolated star ground system as documented in this paper serves all of these purposes: safety, reliability, cost efficiency and control of electromagnetic interference.

Grounding is only one means of controlling electrical noise in audio and other technical systems. A systems approach to controlling noise is recommended and readers should see [1], [2], [3], [4], [5], [6] and the references contained therein.

This paper discusses the grounding system installed in the facility up to but not including the electronic equipment. Grounding practices at electronic equipment and shields are discussed in the references.

2. System Concept

The overall concept of the isolated star ground system is shown in Figure 1. From this drawing we see that the technical ground wiring connections occur in four locations; these being the service entrance, the sub distribution panel, the area panels and the final equipment connections (branch circuits). These are discussed in the following paragraphs.

The distribution of non-technical (safety) equipment ground is shown on all the drawings via the conduit system, as permitted by many electrical codes. In some cases, this is, or must be, supplemented with an added ground conductor to reinforce the integrity of the bonding of the conduit system. Of course, in the case of armored cable in the branch circuits, the third (ground) conductor is standard practice. Note that equipment racks and large technical units are not considered part of the equipment ground system. They are part of the technical ground system and are discussed later.

The technical ground system is isolated from all metallic building structures. To this end all ground conductors are insulated (green or green with yellow trace or as required by code) and ground bars in the main and area ground boxes are isolated from their metal housings.

2.1. Service Entrance

The wiring diagram for the Service Entrance ground is shown in Figure 1. At this point only, the technical ground is bonded to the main building ground connection which in turn is bonded to the neutral and the earth electrode. Typically the metallic structure of the building will have a connection to ground via contact with electrical conduits and other bonded elements.

The main power distribution panel may be shared with regular power distribution systems in the service entrance as shown in Figure 2. For completeness regular power distribution has been shown to highlight wiring differences.

2.2. Sub

The wiring diagram for the Main Technical ground is detailed in Figure 2. The Main Technical Ground is the central star point of a system. This is where the main technical ground bus resides. All technical grounds stem from this single point.

The main technical ground and associated AC panel would typically be located at the main technical equipment center of the facility, such as a master control room in a broadcast centre.

The main technical ground bus resides in a separate box below the technical sub distribution panel and, as mentioned earlier, it is totally isolated from its enclosure.

2.3. Area

The wiring diagram for a typical Area Technical Ground is shown in Figure 3. Located throughout the facility or adjacent to the main equipment centres (such as studio control rooms) will be technical power branch panels fed from the technical power sub distribution panel. The area technical grounds are wired in a similar manner to the main technical ground panel -- there is an isolated ground bus in a separate box located below the electrical panel. This isolated ground bus receives its ground reference from the ground bus in the technical sub distribution panel. The area technical ground bus provides the ground reference for the equipment or branch technical circuits in the adjacent area.

2.4. Equipment or Branch Circuits

The wiring diagrams for the Equipment or Branch Technical Grounds are shown in Figures 3, 4 and 5. The branch circuits are AC isolated ground receptacles for the use of stand-alone or portable equipment and are detailed in Figure 3. The drawing shows the difference in the wiring practices between technical receptacles and regular receptacles. No more than two receptacles are looped together on a single conductor from the ground bus. In North America, isolated ground receptacles are salmon or orange colored and may have a triangle symbol on the front face identifying that the ground terminal is isolated from the casing and hence the box it is mounted in.

Figures 4 and 5 demonstrate how the equipment racks and large technical units (such as audio consoles) must be isolated and receive their ground connection only from the incoming insulated technical ground conductor. All racks are mounted on an insulating plinth (base). In the case of a multiple rack installation they are bolted together to provide an equipotential plane. All stand- alone equipment must be isolated to prevent the possibility of inadvertent ground contact with metallic building structures. In the case of multiple equipment racks and audio consoles the separate ground conductor from the junction box to the equipment should have an overall protective sheathing to eliminate inadvertent insulation damage. Junction boxes "J" as shown in the figures must be isolated from the technical equipment housings and are wired to the technical equipment via insulated sheathed cable.

3. Conductor Termination

In order to maintain the low impedance of the technical grounding system, conductor termination must be carefully executed. Bus bars should be heavy gauge copper. All hardware should be of stainless steel or brass. All wire termination lugs are copper or copper plated with either nickel or tin. Grounding conductors should be copper. To ensure long term reliability of ground connections, machine screws should be highly torqued. In humid or damp locations the entire assembly should be coated with a moisture proof barrier. Aluminum wire and termination hardware and aluminum bus bars should not be used.

4. Conductor Sizes

4.1. Safety Consideration

The isolated conductors also serve as the equipment (Safety) ground for the technical equipment housings as required by the electrical code. As a minimum requirement, these conductors must satisfy the electrical code. The minimum equipment ground conductor sizes required by the National Electrical Code in the United States and the Canadian Electrical Code in Canada are given in the following table. Other countries have similar wiring regulations.

Minimum Equipment Ground Conductor Sizes (based on National Electrical Code table 250-95 "Minimum Size Equipment Ground Conductors for Grounding Raceway and Equipment")

Rating or Setting of Automatic Overcurrent Device in Circuit Ahead of Equipment, Not Exceeding (A)	Copper Wire AWG (square millimeters)	Aluminum or Copperclad Aluminum Wire AWG (square millimeters)
15	14 (2.081)	12 (3.309)
20	12 (3.309)	10 (5.261)
30	10 (5.261)	8 (8.366)
40	10 (5.261)	8 (8.366)
60	10 (5.261)	8 (8.366)
100	8 (8.366)	6 (13.30)
200	6 (13.30)	4 (21.18)

4.2. Technical Consideration

The sizing of the conductor with regard to the requirements for Electro-Magnetic Interference (EMI) control is more difficult to determine. The appropriate wire gauge for EMI reasons is influenced by the sensitivity of the system and the anticipated level of electromagnetic interference. Obviously systems of low dynamic range such as paging and background music systems do not have stringent requirements for technical grounding whereas broadcast and post- production complexes are more critical. Wire gauges typical of a broadcast installation, are shown in the figures. The following table gives suggested values [1].

Technical Ground Conductor Sizes in AWG (square millimeters) (Suggested Only)

Conductor Out From	Low Dynamic Range (< 60 dB)	Medium Dynamic Range (60 to 80 dB)		High Dynamic Range (>80 dB)	
		Lo EMI	Hi EMI	Lo EMI	Hi EMI
Ground electrode to main bus	6 (13.30)	2 (33.63)	00 (67.45)	00 (67.45)	0000 (107.2)
Main bus to Local bus	10 (5.261)	8 (8.366)	6 (13.30)	4 (21.18)	0 (53.48)
Local bus to single unit/rack or receptacles	14 (2.081)	12 (3.309)	12 (3.309)	12 (3.309)	10 (5.261)
Local bus to multiple units/racks or major equipment	14 (2.081)	12 (3.309)	10 (5.261)	8 (8.366)	4 (21.18)

Maximum resistance (ohms) for any cable	0.5	0.1	0.001	0.001	0.0001

In all cases the ground conductor must be suitably rated for the overcurrent device of its associated power conductors.

5. Conductor Separation and Routing

The electrical code requires that the ground conductor must be routed with its associated power conductors. Exceptions have been made in some cases, but special approvals may be required. The authors have not been able to determine whether there is any benefit from running ground conductors separately. Further work will follow in this regard.

As the ground conductor is sensitive to EMI the routing of the technical power and ground conductors should be done with some care and should be routed away from other major high voltage feeders, transformers, large motors and other EMI sources in the building.

6. Conclusion

The most widely accepted approach to the implementation of a isolated star ground system has been presented. It is suggested that from a value engineering stand point, this approach represents an appropriate level of system design and installation practice. If EMI problems exist in technical systems so implemented it is suggested that designers and trouble shooters look for solutions in areas other than grounding. These areas include interconnection schemes, internal ground of electronic equipment ("the pin 1 problem") and overall systems design.

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7. References

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