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The Industry Standard Guide to Electrical Earth Monitoring

Guide

0 Introduction

The possibility of damage to, disconnection from, or a rise in impedance of, any protective conductor, cannot be eliminated by periodic inspection and, in any event, accidental damage could occur between inspections. For example, trailing cables supplying portable or transportable equipment such as conveyors, pumps and generators, are particularly vulnerable to faults in the protective conductor due to mechanical damage or excessive strain.

Earth monitoring may be applied in certain special applications in fixed installations where the integrity of the protective conductor is vital to the safety of the system and where protective conductors are particularly vulnerable.

Earth monitoring devices are intended to maintain a continuous check on the integrity of the protective earth conductor. They do not of themselves ensure protection against earth fault currents, which would normally be provided by overcurrent protective devices or by some forms of earth fault circuit breaker.

If the earth connection is severed or deteriorates and if the appliance or equipment develops an earth fault then the overcurrent protective device used to give protection against indirect contact will not operate and the user may receive an electrical shock, which if not fatal in itself, may cause a fall from a height or against moving machinery.

The various devices covered by this guide provide methods of checking the integrity of the earth connections and establish whether the earth return paths are in a healthy state to carry earth fault currents. High resistance earth fault currents due to insulation deterioration are not normally detected by overcurrent protective devices such as fuses and miniature circuit breakers. In these cases, a residual current device should be used in conjunction with the earth monitoring or proving device to provide protection.

1 Scope

This British Standard explains the principles involved in the design and construction of earth monitoring, earth proving and insulation monitoring devices, together with the requirements for their safe use and application.

Systems of earth fault protection are given in Appendix A and special requirements for protection of data processing equipment are described in Appendix B.

2 Definitions

For the purposes of this British Standard the following definitions apply.

2.1 earth proving system. A system for providing a means of maintaining a high degree of confidence in the continuity of a protective conductor within the installation.

2.2 earth monitoring system. A system for providing a means of maintaining a high degree of confidence in the measured impedance of a protective conductor forming part of the earthing arrangements of an electrical system.

2.3 functional earthing system. A system of earthing provided in an installation where earth currents flow due to the normal function of load apparatus.

NOTE. This system is additional to the protective earthing arrangements.

2.4 residual current protection system. A system for providing a means of detecting and interrupting the supply in the event of unintentional residual currents flowing and thereby giving additional protection against dangerous electric shock and fire hazards caused by the flow of such currents.
NOTE. These residual currents are usually much smaller than those required to blow a fuse or trip a circuit breaker.

2.5 voltage operated earth fault system. A system, which uses a voltage-sensing device and is designed to minimise the risk of dangerous electric shock by interrupting the supply if the apparatus casing reaches a potential substantially different from that of its surroundings.
NOTE. AC voltage-operated earth leakage circuit breakers are specified in BS 842.

2.6 earth leakage current. A current that flows to earth, or to extraneous conductive parts, in a circuit, which is electrically sound.
NOTE. This current may have a capacitive component including that resulting from the deliberate use of capacitors.

2.7 fault current. A current resulting from an insulation failure or the bridging of insulation.

2.8 earth fault current. A fault current, which flows to earth.

3 Earth proving systems

An earth proving system provides a means of establishing a degree of confidence in the continuity of the protective conductor from the proving unit to the remote protected apparatus. No provision is made for impedance measuring but designs centred around the use of specialised relays afford a coarse method of proving.

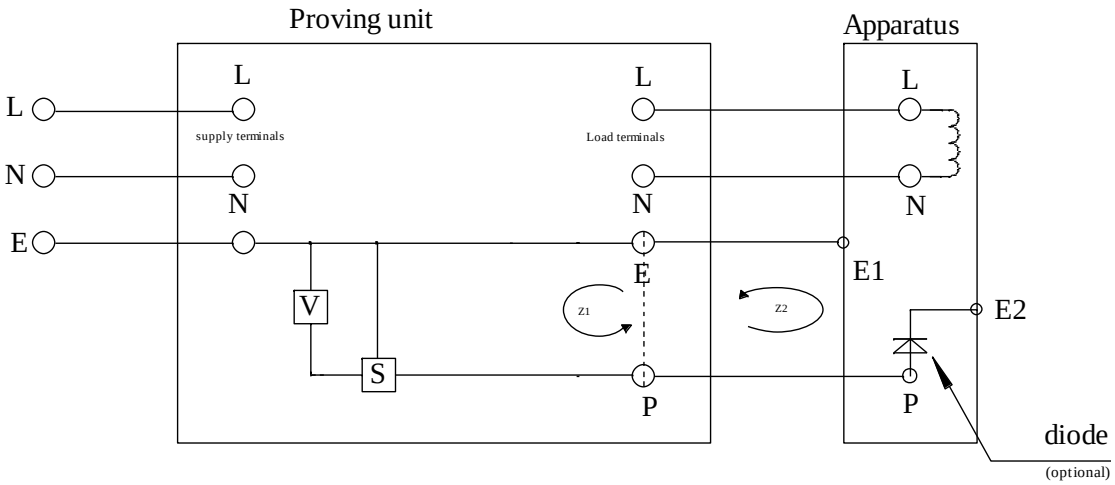
The proving unit may be connected anywhere between the origin of the installation and the apparatus to be protected. Detection of short circuits between pilot and protective conductors may be achieved by the use of d.c sensitive relays as part of the proving system.

Continuity may be proved with a shunt-connected voltage-sensing device or a series connected current sensing device. In either case, the protective conductor should be a substantial earth path of low impedance. The impendence of the source and detector combination Z_1 (see figure 1) should appear in series with the pilot earth path.

The total impedance of the monitored loop will be the vector sum of the impedance Z_1 and the impedance of the rest of the loop Z_2 A value of Z_2 in excess of about 10 Ω should prevent the load apparatus being energised.

Furthermore, after the apparatus has been energised, if the monitored loop becomes open-circuited or increases in impedance beyond about 20 Ω the apparatus should become isolated.
NOTE. The impedance values quoted above are only typical and need to be considered in the light of specific applications.

Figure 1. Basic circuit for earth proving unit



Key

E1 Protective earth terminal

E2 Earth terminal for pilot circuit(this may be internal or external)

P Pilot conductor terminal

S Sensing device

V Extra low voltage source

Z1 Impedance of source

Z2 Impedance of the loops

NOTE: If a diode is not used then alink has to be provided for a direct connection between terminals P and E2

The proving current circulates in a loop circuit, which contains the protective conductor to the apparatus, a section of the apparatus casing and a suitable return path. It is essential that any plug and socket and flexible cable therefore, provide not only the main protective path but also a return path, which is usually known as the pilot conductor.
It is essential that the proving unit itself be properly earthed in accordance with the Regulations for Electrical Installations published by the Institution of Electrical Engineers. The requirement that the earth loop contains a section of the apparatus casing, otherwise there would be a risk of both conductors becoming detached from the casing whilst still maintaining the monitored loop.
It is worth noting that although the main and pilot paths are monitored in series, they function in parallel as far as actual earth-fault currents are concerne

4 Earth monitoring systems

An earth monitoring system provides a means of maintaining a high degree of confidence in the impedance level of the protective conductor from the monitoring unit to the remote protected apparatus. The monitoring unit may be connected between the source of energy (if accessible) and the apparatus to be protected.

NOTE. The source of energy may be, for example, a generator or a transformer.

Earth monitoring depends upon the continuous circulation of a small current at a voltage not exceeding 12V derived from a safety extra low voltage source. An interruption of this current is arranged to bring about disconnection of the protected apparatus from the supply.

The monitoring current circulates in a loop circuit that contains the protective conductor to the apparatus, a section of the equipment casing and a suitable return path. It is therefore essential that any plug and socket and flexible cable provide not only the main protective path but also a return path, which is usually known as the pilot conductor.

It is worth noting that although the main and pilot paths are monitored in series, they function in parallel as far as actual earth-fault currents are concerned.

It is essential that the monitoring unit itself be properly earthed in accordance with the Regulations for Electrical Engineers. The requirement that the earth loop contains a section of the apparatus casing, necessitates the provision of two independent earth terminals on the casing, otherwise there would be a risk of both conductors becoming detached from the casing whilst still maintaining the monitored loop.

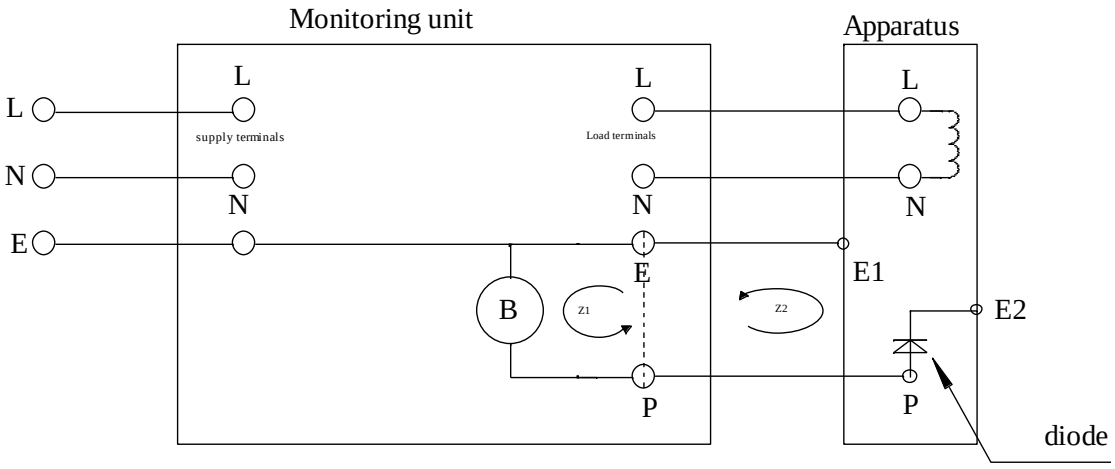
The impedance of the protective and pilot conductors forms part of a balanced bridge network (see figure 2). The balance will be disturbed by variations in the parameters of the loop (e.g. open circuit or short circuit) and this can initiate a signal or disconnection.

Typical impedance sensitivities of the balance bridge network (-10°C to + 40°C) are:

(a) for domestic installations, 4 ± 2 Ω:

(b) for industrial installations, 8 ± 2 Ω.

Figure 2. Basic circuit for earth monitoring unit



Key

B Balancing and sensing network

E1 Protective earth terminal

E2 Earth terminal for pilot circuit(this may be internal or external)

P Pilot conductor terminal

Z1 Impedance of source

Z2 Impedance of the loops

5 *Practical arrangements*

NOTE. There are several methods by which a protective conductor proving or monitoring unit may be used, depending on where the unit is sited and on how it is connected. The methods covered in this guide are described in 5.1 to 5.3.

5.1 Method A

Method A proves or monitors the protective conductor and pilot conductor loop in a flexible trailing cable supplying a transportable or mobile apparatus, the proving or monitoring unit being arranged to disconnect the supply to the apparatus at the point of connection of the trailing cable to the wiring installation.

This method is the more usual. A wall mounted protective conductor proving or monitoring unit is directly connected to a section of the fixed electrical installation and is arranged to feed the flexible trailing cable, which may be connected to the unit either by means of a plug and socket or by a permanent connection. When connected in this manner both the trailing cable as well as the apparatus will be disconnected when the unit operates in the event of failure of the monitored loop.

5.2 Method B

Method B proves or monitors the protective conductor and pilot conductor loop in a flexible trailing cable supplying a transportable or mobile apparatus, the proving or monitoring unit being arranged to disconnect the supply to that apparatus at the point of connection of the trailing cable to the apparatus. This method may be employed where the fixed wiring installation is not provided with a proving or monitoring unit and where there is a need to be able to connect a transportable or mobile apparatus. In this case a protective conductor proving or monitoring unit is mounted on the apparatus itself, its purpose being to prove or monitor the protective conductor of the supply cable. In effect, the protective conductor proving or monitoring unit has been transferred from a fixed site to a mobile one and the flexible cable is now on its supply side instead of its load side. It should be noted that, in such a case, the protective conductor proving or monitoring unit disconnects the load but cannot necessarily isolate the trailing cable which is supplying it; as well as disconnecting the load, the unit can be arranged to give an alarm. Any protective conductor fault occurring on the trailing cable has to be cleared by other means. It is important that a plug and socket with separate protective conductor and pilot connections be used to carry the loop through the fixed portion of the wiring and it is recommended that these connections be made in the manner shown in figure 3.

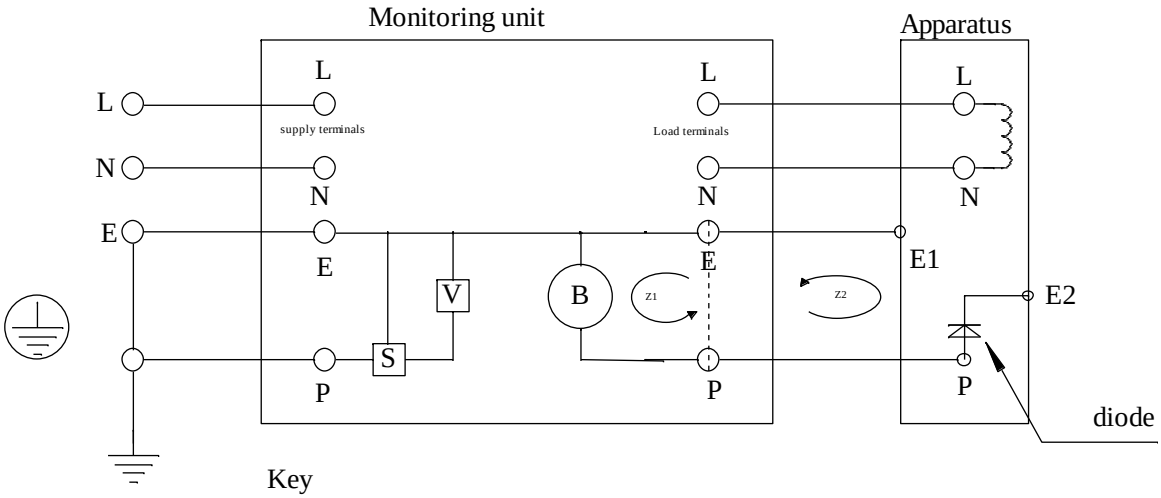
5.3 Method C

Method C proves or monitors the protective conductor and pilot conductor loop in cables in the fixed wiring installation, the proving or monitoring unit being arranged to disconnect the supply to those cables and to any transportable or mobile apparatus connecting that apparatus to the fixed wiring installation. In this method the cables in the fixed installation are those forming the circuit from the origin of the installation or whatever other point to which it is desired to extend the monitoring facility; the pilot conductors may be integral with the cable(s) or separate.
Again, the unit can only trip the load and initiate an alarm; it cannot isolate the cables on its supply side.
NOTE. Where long protective conductors are employed, the resultant total impedance may adversely affect the functioning of the proving unit. In such cases, an earth monitoring system should be used.

6 Cables

6.1 In order to provide a monitoring or proving loop as well as the protective conductor, flexible trailing and fixed installation cables should also include a pilot conductor which is insulated from the other conductors in the cable; independent from protective conductor terminals so that the monitoring or proving current will circulate through apparatus and fixed wiring installations as applicable. As an example, for a 3-phase 4-wire supply, the cable may be a 6-core cable with or without an earthed metal covering, where one of the cores serves as the protective conductor.

Figure 3. Basic circuit for earth proving and monitoring unit



Key

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Z1 Impedance of source

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6.2 Where flexible trailing cables are vulnerable to damage from vehicles or equipment running over them, it is recommended that cables incorporating an earthed metal covering in the form of a braid protected by a tough oversheath be used. In the event of a metal object penetrating the braid of the cable, there is a high probability that any exposed live conductors of the live metal object will be shorted to the earthed braid and the subsequent fault cleared by an overcurrent and/or earth fault protective device.

6.3 Protective conductor proving or monitoring units that operate with a low value of monitoring current may be susceptible to mutual interference between the load carrying conductors and the pilot conductor, especially if the waveform of the load current is distorted, which may cause nuisance tripping. In this case, consideration should be given to the use of cables in which the protective conductor and pilot conductor are individually screened from each other and from the load current carrying conductors.

7 Plugs, socket outlets, cable couplers and appliance connectors

7.1 Plugs, socket outlets, cable couplers and appliance connectors used for protective conductor proving or monitoring in flexible trailing cables should connect together the protective conductor and pilot conductor in the flexible trailing cables to their counterparts in the proving or monitoring unit and in the load to complete the pilot conductor path and the protective conductor path. These connections should be of the pin and tube type complying with BS 4343 although the scraping earth type complying BS 196 are acceptable. It is essential when exposed conductive parts of the plug etc. can become live in service due to an earth fault, they are reliably connected to the protective conductor.

7.2 When a braided cable is used, plugs etc. should be provided with a satisfactory means of making electrical and mechanical connections to the cable braid.

7.3 The pins of plugs complying with BS 4343 are arranged so that when they are withdrawn the main power supply is interrupted before the protective conductor connection is broken. This is achieved by having shorter pins on the pilot contacts so that the monitoring circuit is broken and the unit trips before the main contacts part.

8 Multi-outlet systems

8.1 Where application of protective conductor proving or monitoring is required for a number of small appliances, the cost of separate units for each socket outlet may not be justifiable. Normally, further socket outlets cannot be added to a single outlet proving or monitoring unite because o f the introduction of possible parallel earth loops which would interfere with the operation of the device. However, a multi-outlet unit can be used without detriment to the protection afforded.

8.2 A multi-outlet unit operates on the principle of there being a number of separate pilot and protective conductor loops, each pilot being insulated from the others but the main protective conductor being common. However, there is a practical limitation because all the outlets will be disconnected when a fault occurs on the cable to any one of the items of connected apparatus.

8.3 In order to prevent the tripping of this proving or monitoring unit when a plug is withdrawn, it is permissible to use an interlocked, switched socket outlet or an automatic connection to maintain the loop when the apparatus is not is use and to direct the loop via the apparatus frame when the apparatus is connected to the supply.

Appendices

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Appendix A Devices for earth fault protection

A.1 Overcurrent devices

Protection by overcurrent devices is the simplest form of earth fault protection and relies upon a low impedance path to the source for any fault current from equipment. It is necessary for the earth fault loop impedance to be low enough to permit sufficient current to flow to blow a fuse or trip a circuit breaker on the occurrence of a fault of negligible impedance to earth. Full details are given in the Regulations for Electrical Installations published by the Institution of Electrical Engineers.

A.2 Residual current operated devices

Protection by residual current operated devices depends for its operation upon the out of balance current flowing being detected by one or more current transformer(s). The transformer(s) may be either part of a circuit breaker, or be separate unit(s) used in conjunction with a relay or contactor etc. It is essential that the transformer(s) is capable of detecting fault currents much smaller than those required to blow a fuse or trip a circuit breaker, and hence has the advantage of giving more sensitive protection. Circuit breakers to BS 4293 provide this method of protection.

A.3 Fault voltage operated devices

Protection by fault voltage operated devices uses a voltage-sensing device to detect a dangerous voltage rise between metal work and its surroundings and interrupts the supply. It is designed to protect against shock risk only and has generally been superseded by current operated earth leakage protection to be unsuited. The sensing device is normally integral with a circuit breaker assembly and a separate earth electrode is required. Fault voltage operated earth leakage circuit breakers should comply with BS 842.

Appendix B Data processing equipment

BS 6204, particularly 13.2 requires that the disconnection of a protective earth conductor at one apparatus does not interrupt the earth connection to other apparatus and thereby cause a shock hazard situation.

In the case of earth monitoring, the use of a single earth and pilot loop connecting several equipments together is not an acceptable method. It is a necessary requirement to avoid parallel earth paths and connect each item separately with its own protective earth conductor and pilot conductor.

In data processing equipment, it is common practice to provide filters connected between phase, neutral and earth conductors in order to prevent:

a) mains interference through the earth system disrupting the data processing;
b) unacceptable input from the data processing equipment into the earthing system.

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The filters used should be designed with inherently low leakage characteristics so that residual current protection can be installed in the normal way. However, this is not always the case, and filter currents could give rise to unwanted tripping of residual current devices (RCD's) unless special precautions are taken. Where the filter currents are of appreciable magnitude the apparatus should be hard wired. A functional earthing system enables use of an RCD for the protection in an installation where for functional and operational reasons there are intentional filter currents flowing to earth. Should the protective conductor(s) become damaged, either high impedance or open circuited, the RCD protection against electric shock is maintained.

Some current using items of apparatus now in common use for household and similar purposes, including personal computers, are generally fitted or used in conjunction with a voltage stabilization device incorporating filters, which are designed to pass an appreciable filter current through the protective conductor.

When a number of such devices are connected to a supply circuit the total sum of the intentional filter currents will cause the RCD protecting the circuit to trip.

Under similar circumstances when a number of such devices are connected to a supply, which is not protected by an RCD the intentional filter current, can present a serious electric shock hazard if the protective earth conductor continuity is disrupted. All normally earthed metal work on that part of the circuit subsequently not earthed will rise towards phase voltage and the prospective shock current being equal; to the sum of all the intentional filter currents normally passing through the protective conductor to earth.

The system provides apparatus for supplying electric current to equipment from an electrical source through phase and neutral conductors. The equipment should be connected to earth through a protective earth conductor to provide a path for unintentional residual currents, and the equipment should be connected to the apparatus through a functional earth conductor to provide a path for the intentional filter current(s). The apparatus also contains a residual current operated device so arranged to disconnect at least the phase and neutral conductors when the unintentional residual current exceeds a predetermined value. The functional earthing conductor incorporates an impedance so that in the event of a short circuit between the protective and functional earth conductors, the RCD will disconnect the supply at a predetermined tripping value.

The apparatus also provides device connected between the functional and protective earth conductors which operates (closes) when the filter current exceed a predetermined value thereby allowing the filter current to flow through the protective earth conductor and cause the RCD to disconnect the phase and neutral conductors.

The RCD may comprise a transformer through which the phase, neutral and functional earthing conductor pass (but not the protective earth conduction), and a non zero victor sum on the current sin the conductors passing through the transformer would cause the RCD to trip if it exceeded a predetermined value.