WIRING MATTERS

Issue 82

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Back to the Forum - History of model forms

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Model forms have been discussed many times on the IET forum over the years. In this article, we take a look at their history.

In the early days of the IEE Wiring Regulations, examples of model forms were not provided. However, contrary to popular belief, there was certainly a requirement for testing, even in the First Edition in 1882, Regulation 17 stated:

"N.B. The value of frequently testing the wires cannot be too strongly urged, it is an operation, skill in which is easily acquired and applied. The escape of electricity cannot be detected by the sense of smell as can gas, but it can be detected by apparatus far more certain and delicate. Leakage not only means waste but in the presence of moisture it means destruction of the conductor and its insulating covering, by electric action."

The Second Edition of the IEE Wiring Regulations was published in 1888. It was more prescriptive and stated that "***records should be kept of all tests, so that any gradual deterioration of the system may be detected***". This was probably the first requirement for a schedule of test results, although no examples were provided.

Form A *prescribed in the I.E.E. Regulations for the Electrical Equipment of Buildings.*

Initial Certificate to be given by the contractor responsible for the construction of the installation, or by an authorized person acting on his behalf.

Electrical installation at ....
........Lighting points Fixed apparatus..........
.... -amp. socket-outlets ....

Certificate. I certify that the installation detailed above has been inspected and tested and that, to the best of my knowledge and belief, it complies with the Edition of the Regulations for the Electrical Equipment of Buildings published by The Institution of Electrical Engineers and current at the date of contract for the work, except as stated below.

I recommend that this installation be periodically inspected and tested at intervals of not more than .... years, and a report obtained on its condition, as prescribed in the above Regulations.

Signed ....
Date ....
Details of departures (if any) from the Regulations:—

NOTE.—It is recommended that the contractor or other person responsible for the construction of an installation should remind the consumer of the importance of re-inspection at the appropriate time. Every re-inspection of an installation should be reported upon on the form (Form B) set out below, which should be submitted to such consumer and be signed by a competent person who should preferably be a Chartered Electrical Engineer, a member of the Electrical Contractors' Association Inc., a member of the Electrical Contractors' Association of Scotland, a certificate holder of the National Register of Electrical Installation Contractors, or a qualified person acting on behalf of one of these (in which event it should be stated for whom he is acting).

Form B *prescribed in the I.E.E. Regulations for the Electrical Equipment of Buildings.*

Maintenance Report.

I certify that the installation at..........................
has been inspected and that:—

(*a*) The value of insulation resistance to earth is (*see* Regulation 1103)...............................
(*b*) The value of impedance of earth-continuity path is (*see* Regulation 1106)...............................
(*c*) The earthing is in accordance with the requirements of the Regulations, except as stated below.
(*d*) All flexible cords, switches, fuses, plugs, and socket-outlets, are in good serviceable condition, except as stated below.
(*e*) There is no sign of overloading of conductors or accessories, except as stated below.
(*f*) There is no evidence (after inquiry) of the use of portable appliances in any bathroom, except as stated below.
(*g*) There are no obvious defects, and the whole installation appears to be in good serviceable condition, except as stated below.

Signed ....
Date ....
Details of defects and exceptions, if any, referred to above:—

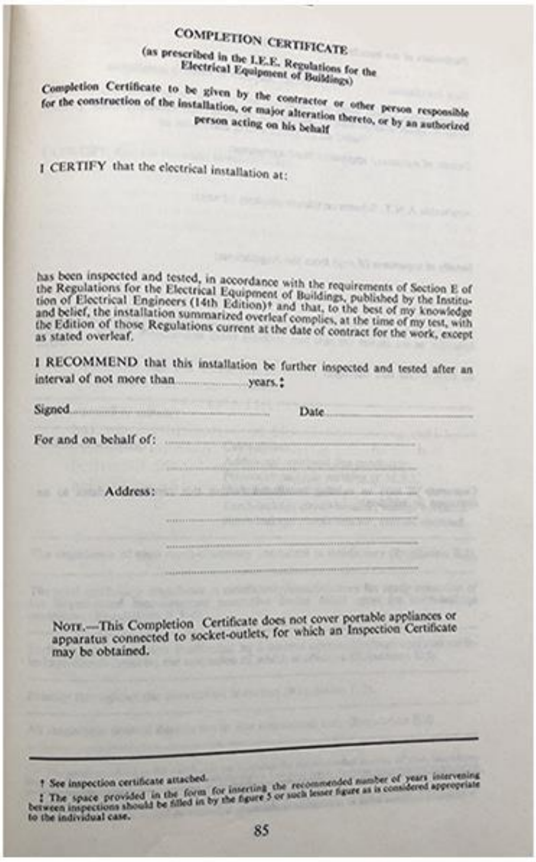
The first actual electrical certificate in the IEE Wiring Regulations dates back to 1939 when Regulation 1108 of the Eleventh Edition stated:

"on completion of an installation, (or an extension to an installation) a certificate shall be given by the contractor, or by an authorised person acting on his behalf on form A. The space provided in the form for inserting the recommended number of years intervening between inspections should be filled in with the figure 5 or such lesser figure as is considered appropriate to the individual case."

(Note that the IEE felt justified at the time in assuming the electrician would be male – times have changed!) The statement suggests a maximum frequency for inspection and testing of five years, with an emphasis on the requirement for the person completing the report to reduce the interval between inspections if required, which is still the same today.

Guidance on inspection intervals can be found in IET Guidance Note 3 *Inspection & Testing*; however, these frequencies are for initial inspection and are only recommendations. Inspection and testing intervals should be determined by the inspector, making an engineering judgement based on several different factors, such as the environment, age, use and condition of the installation.

A separate form for inspection of an installation debuted in the Fourteenth Edition of the IEE Wiring Regulations, published in 1966. A completion certificate was intended for new installations or alterations, but for the first time, an inspection certificate was included, intended to be used for carrying out inspection and testing on an existing installation.


COMPLETION CERTIFICATE
(as prescribed in the I.E.E. Regulations for the Electrical Equipment of Buildings)

Completion Certificate to be given by the contractor or other person responsible for the construction of the installation, or major alteration thereto, or by an authorized person acting on his behalf

I CERTIFY that the electrical installation at:

has been inspected and tested, in accordance with the requirements of Section E of the Regulations for the Electrical Equipment of Buildings, published by the Institution of Electrical Engineers (14th Edition)† and that, to the best of my knowledge and belief, the installation summarized overleaf complies, at the time of my test, with the Edition of those Regulations current at the date of contract for the work, except as stated overleaf.

I RECOMMEND that this installation be further inspected and tested after an interval of not more than .... years.‡

Signed .... Date ....

For and on behalf of: ....

Address: ....

NOTE.—This Completion Certificate does not cover portable appliances or apparatus connected to socket-outlets, for which an Inspection Certificate may be obtained.

† See inspection certificate attached.
‡ The space provided in the form for inserting the recommended number of years intervening between inspections should be filled in by the figure 5 or such lesser figure as is considered appropriate to the individual case.

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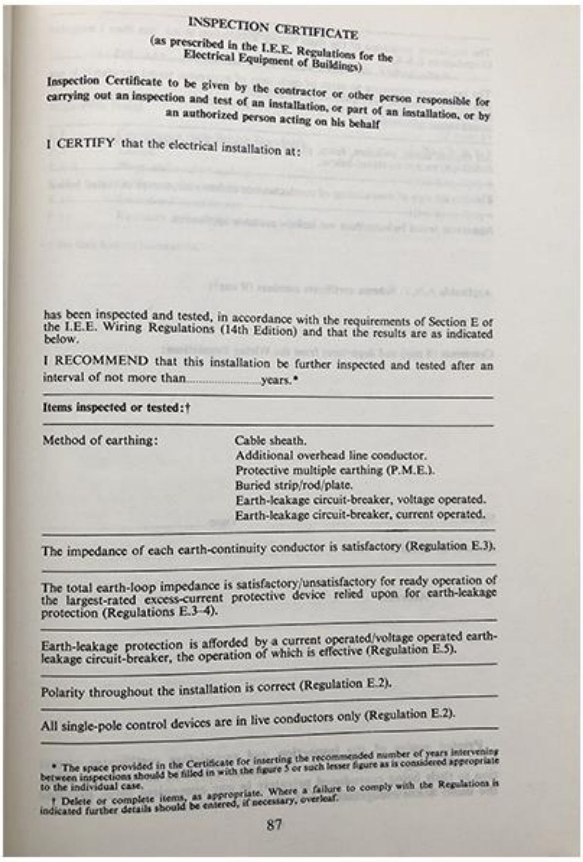
INSPECTION CERTIFICATE
(as prescribed in the I.E.E. Regulations for the Electrical Equipment of Buildings)

Inspection Certificate to be given by the contractor or other person responsible for carrying out an inspection and test of an installation, or part of an installation, or by an authorized person acting on his behalf

I CERTIFY that the electrical installation at:

has been inspected and tested, in accordance with the requirements of Section E of the I.E.E. Wiring Regulations (14th Edition) and that the results are as indicated below.

I RECOMMEND that this installation be further inspected and tested after an interval of not more than .... years.*

Items inspected or tested:†

Method of earthing: Cable sheath.
Additional overhead line conductor.
Protective multiple earthing (P.M.E.).
Buried strip/rod/plate.
Earth-leakage circuit-breaker, voltage operated.
Earth-leakage circuit-breaker, current operated.

The impedance of each earth-continuity conductor is satisfactory (Regulation E.3).

The total earth-loop impedance is satisfactory/unsatisfactory for ready operation of the largest-rated excess-current protective device relied upon for earth-leakage protection (Regulations E.3-4).

Earth-leakage protection is afforded by a current operated/voltage operated earth-leakage circuit-breaker, the operation of which is effective (Regulation E.5).

Polarity throughout the installation is correct (Regulation E.2).

All single-pole control devices are in live conductors only (Regulation E.2).

* The space provided in the Certificate for inserting the recommended number of years intervening between inspections should be filled in with the figure 5 or such lesser figure as is considered appropriate to the individual case.
† Delete or complete items, as appropriate. Where a failure to comply with the Regulations is indicated further details should be entered, if necessary, overleaf.

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This format remained the same until the Sixteenth Edition, at which time the IEE Wiring Regulations became BS 7671, a joint publication between the IEE and BSI. This is the period at which the model forms were amended to the format we recognise today. The completion certificate became the Electrical Installation Certificate (EIC), in order to avoid confusion with the completion certificates issued at handover of a building by the construction industry. The inspection certificate became the Periodic Inspection Report (PIR), which, by the time of the Eighteenth Edition (BS 7671:2018+A1:2020), was known as the Electrical Installation Condition Report (EICR).

The Minor Works Electrical Installation Certificate (MEIWC) is the new kid on the block, with its first appearance in BS 7671:2001, the Sixteenth Edition of the IET Wiring Regulations. This certificate is intended to be used for minor electrical work that does not include the provision of a new circuit, for example, an additional socket-outlet to an existing circuit.

Whilst there have been minor amendments to the model forms to incorporate changes in the Regulations since the Sixteenth Edition of the IEE Wiring Regulations, the model forms in Appendix 6 of the Eighteenth Edition are not much different.

The model forms were adopted in the international document IEC 60364-6:2006 and the equivalent European CENELEC HD 60364-6:2006. In fact, it was a UK proposal to include the model forms, and the maintenance team responsible for the development of the international document was convened by the UK.

The model forms can be found in BS 7671:2018+A1:2020, or downloaded from our website. It should be remembered that the forms can be modified to suit the installation, providing they meet the minimum requirements set out in Appendix 6. Trade associations and other organizations provide their own versions of the forms, which may differ from the model forms.
There is no doubt that debate over classification codes for EICRs and other intricacies with model forms will continue: items on the inspection schedule have provided a good basis for discussion over the years.

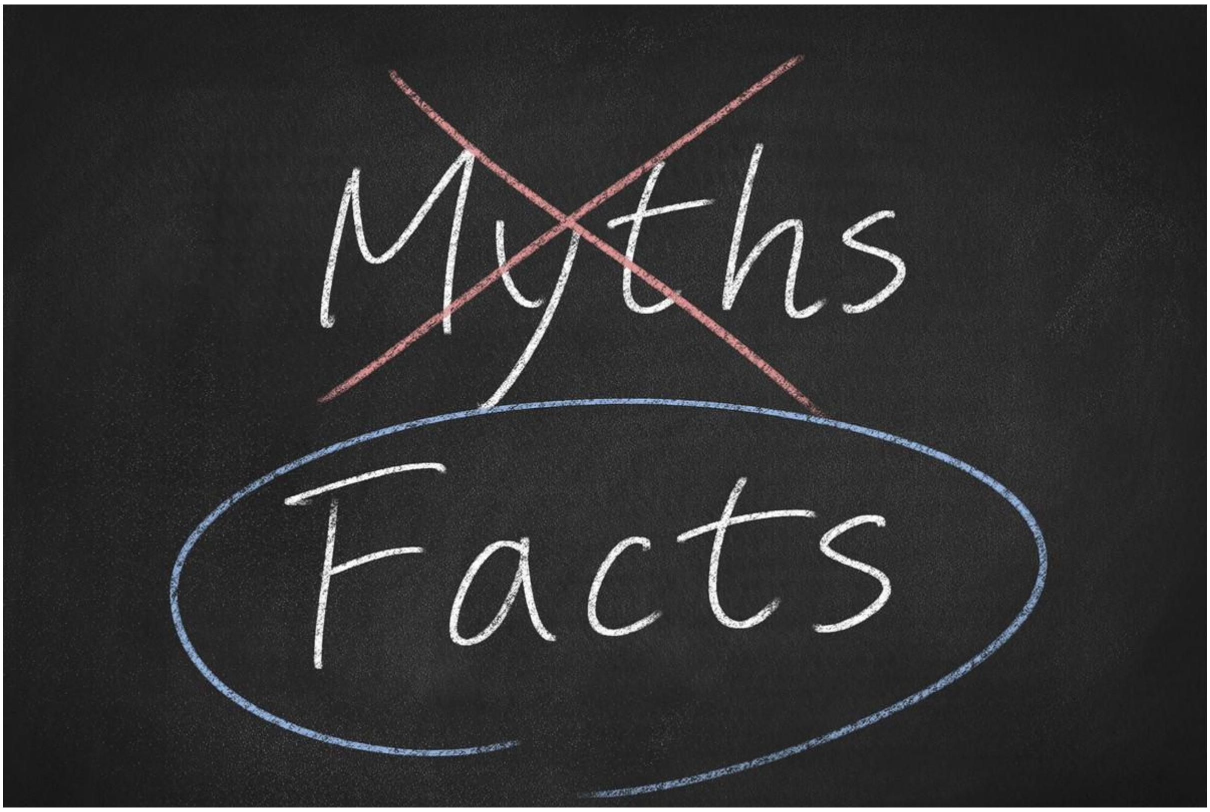
Summary

Whilst the format and content of the model forms have changed over the years, the purpose is still the same as it has always been, which is to provide a record of the details for the installation and the person(s) responsible.

The frequency of inspection and testing should be determined by engineering judgement made by the electrical designer or inspector.

Model forms are exactly that: they can be modified to suit the installation requirements.

Remember, you can visit our Engineering Communities forum yourself and join the discussion.



MythBusters #6

By: **James Eade**

This month, James Eade looks at his specialist subject of temporary power and, in particular, the earthing of temporary generator sets.

True or false? All generators need to be earthed unless floating

Being a mythbuster column, this statement is, of course, untrue – not least because the term 'floating' is technically undefined, so is a meaningless expression. The earthing of generator sets has long been a source of confusion, particularly with smaller units like those used to power mobile units, such as catering vans or offices on construction sites.

The issue is not just with the way in which generator sets are used however, it is not uncommon for manufacturers' instructions to be confused on the subject too. It is not unusual to see in generator operator manuals a requirement that the generator frame must be connected to an earth electrode, when in practice (given the way the alternator is configured), doing so will provide absolutely no benefit or electrical protection whatsoever.

It is often said that a generator must be 'referenced' to Earth. This again is a myth – in typical low voltage generators the mass of Earth plays no part in the electrical performance of the alternator (or inverter), and a generating set will still output 230 V, whether the frame or winding(s) is connected to Earth or not. But Earth can be, and is, used for *fault protection* with low-voltage generator based installations.

The history

Most guidance in the area of generator earthing stems from BS 7430 *Code of Practice for protective earthing of electrical installations*. This document has been updated many times in recent years and provides useful advice on designing earth electrode networks, the earthing of low and high voltage installations, and more. However, the sections covering generators were for a long time based on two rather historic principles – namely, that generators under 10 kVA typically didn't need earthing, and that those over 10 kVA did. Most guidance published to date has been based on these two options.

Putting it into perspective, it is just as possible to get an injurious electric shock from a 2 kVA generator as it is from a 12 kVA one. It is unclear what the original engineering rationale was for the different power levels; it is probably a legacy of early generating set topologies when alternator configurations were quite simple and uniform.

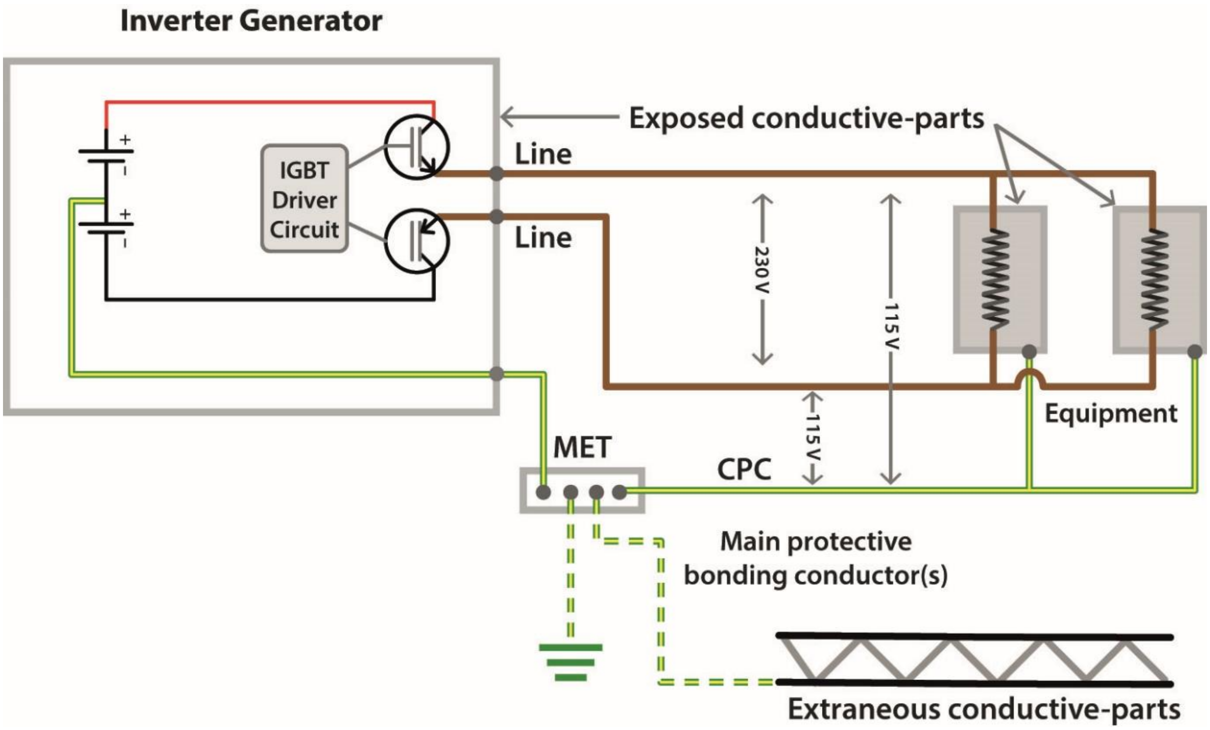
The situation today

Much has changed over the years; alternators and their wiring configurations now come in a variety of configurations, including switchable single- or three-phase, star or delta, 110 V and 230 V dual outputs, self-exciting regulation and automatic regulation – and we are also now seeing inverter-based generators, designed to handle modern loads without issue. This is because the ubiquitous switched-mode power supply (SMPS), found in everything from PCs to LED lights, typically have power factors (PFs) near to unity. However, the PFs of the supplies tend to be slightly capacitive (leading) rather than inductive (lagging) and this causes instability in alternators, usually resulting in the generator shutting down or hunting.

A generator can work with quite inductive loads (they just burn more fuel, hence power factor correction (PFC) is popular), but if the PF swings the other way and becomes even mildly capacitive, generators struggle considerably, as the leading current causes (in broad terms) the alternator to accelerate. This explains the growing popularity of the inverter topology (Figure 1); this design will operate with a wide range of leading or lagging PF loads.

The topology in Figure 1 can confuse many, as the earth is 'centre-tapped' about the supply rails. This gives 115 V between line and earth and 230 V between lines. Most multifunction test instruments will see this as a fault and refuse to function; if you join earth and 'neutral' together to create a traditional set-up, then the output devices will fail catastrophically.

Figure 1 Inverter generator topology

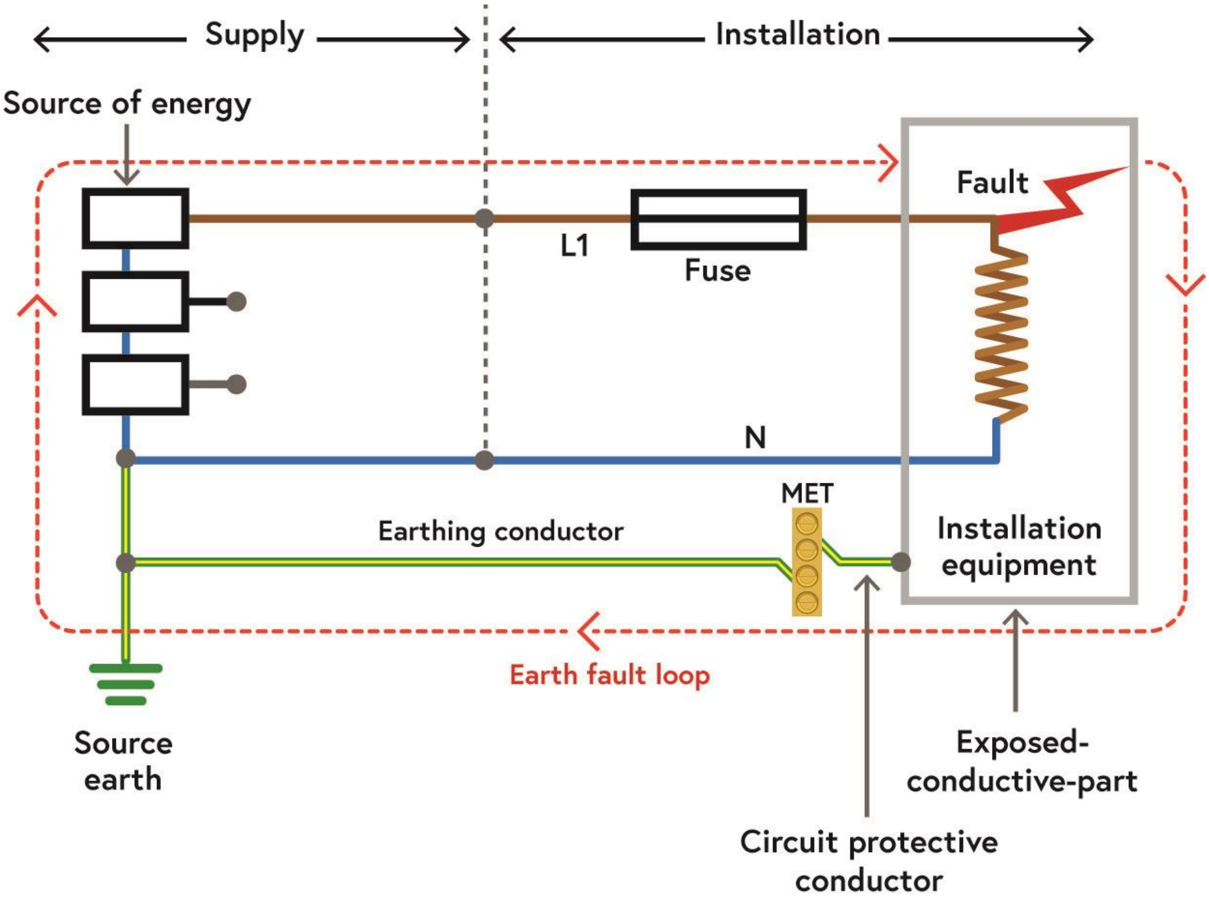


Some alternators are wired in a similar fashion, with the protective earth centre-tapped to the winding – in much the same way as the Reduced Low Voltage (RLV) system is designed, but with twice the operating voltage. Again, trying to connect a line and earth together will result in a shorted winding and potentially a big bill. The arrangement in Figure 1 is actually TN-S (if the earth electrode is deployed) and can be treated as such.

And the answer to the earthing question is….?

It all depends on the way the generator output is wired. It's worth also at this point reminding ourselves of what role the mass of Earth plays in electrical safety in this low-voltage context. Consider a simple circuit such as that in Figure 2.

Figure 2 Simple circuit showing the fault path



When the fault occurs in the equipment, current flows from the phase winding at the source, through the fuse, the casing of the equipment and back down the circuit protective conductor (CPC) to the neutral, before returning to the transformer. No current flows anywhere near the mass of Earth and even if the electrodes in Figure 2 were removed, the fuse should still operate in the event of the fault.

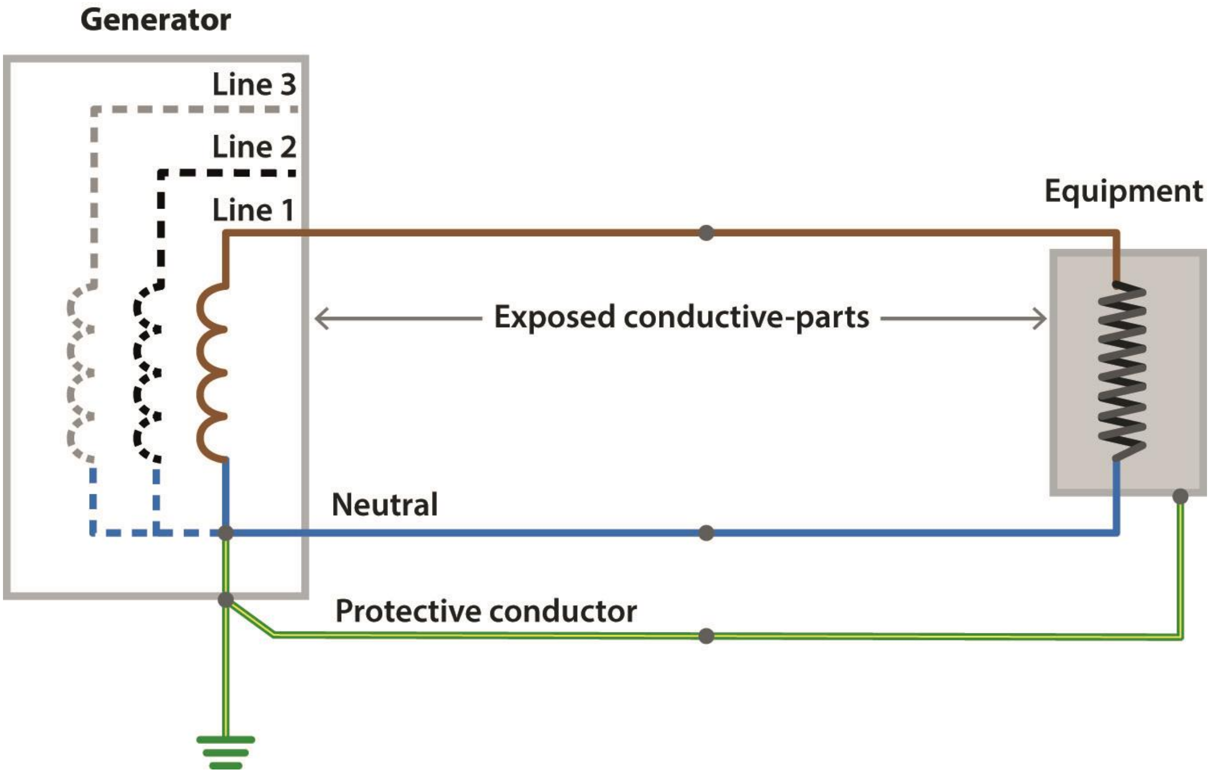
However, if the supply cable is damaged and a line conductor makes contact with Earth, current will flow through the mass of Earth, through the earth electrodes and back to the transformer winding. This will hopefully operate the protective device protecting the cable itself.

The key underlying theme is therefore that the mass of Earth is used for fault detection, typically for the failure of the insulation of cables. But what if you don't use Earth for that purpose? With a generator that is not electrically connected with the mass of Earth, Earth itself plays no part and is not part of the electrical system. This is typified in the age-old problem of what to do with generators parked on a hard-standing where it is not possible to put down an earth electrode. Do you do nothing? Is it safe? Should you dig up the pavement and put one in?

Generator earthing arrangements

There are three typical topologies to consider. Figure 3 shows a generator set configuration that is fairly common and could be described as a 'normal' arrangement.

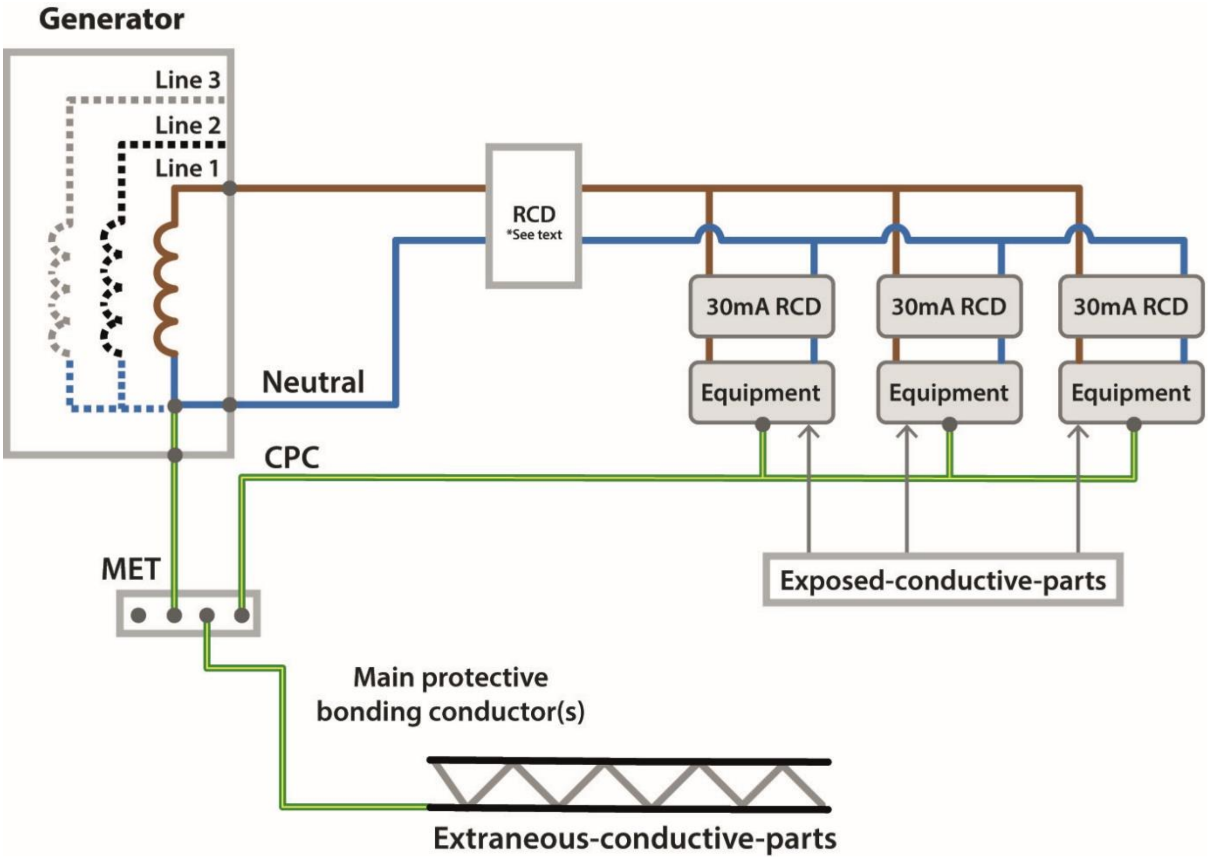
Figure 3 Standard earthed generator topology



In most respects, this is similar to an ordinary electrical supply, with the supply connected to Earth and a separate neutral and protective conductor provided – i.e. TN-S. As a result of the earth electrode being used at the generator, a common mistake on certificates is to see this arrangement described as TT, which it isn't. The earth electrode at the generator in Figure 3 represents the first 'T' in TN-S, and not the second 'T' in TT.

Figure 4 shows the same topology, but without the earth electrode. This is one of the generator configurations that is addressed in the IET *Practitioner's Guide to Temporary Power Systems* and is defined in the guidance as a 'floating' system. The protective conductor still functions to protect equipment, but Earth plays no part in this. As noted, 'floating' is an undefined term in any standard and is often used to describe the arrangement in Figure 4 as well as that in Figure 5. The IET Guide defines Figure 4 as a floating system as it operates as a TN-S arrangement, but the protective conductor is floating from Earth and hence is better described as IN-S rather than TN-S, because of the lack of earth electrode. The protective conductor arrangement in Figure 5 is not used for fault clearance in the same way.

Figure 4 'Floating' generator configuration



Technically, this topology is a departure from Regulation 411.4.1 of BS 7671:2018+A1:2020, which requires a "reliable and effective connection of the PEN or PE conductors to Earth". However, as illustrated earlier, the connection with Earth may not be required, such as for a generator onboard a mobile unit or a generator supplying a site office via a short length of protected cable. It is a topology also used in installations deploying simple separation, such as for supplies to mobile units depicted in Figure 717.6 of BS 7671:2018+A1:2020. Figure 717.1 also describes a generator-based installation on board a mobile unit, as shown in Figure 4 above.

Such an arrangement is safe if contained within a unit such as those described in Part 7 of BS 7671:2018+A1:2020. It can also be safe for temporary systems in construction and similar, but with provisos. The main one is the use of a residual current device (RCD) on the output of the generator to provide protection against accidental earthing of the system (for example, the frame of the generator sitting in wet mud) or failure of cable insulation.

The RCD must be set at no more than 100 mA with a time delay of no more than 0.2 seconds; this affords a degree of selectivity with downstream devices (i.e. 30 mA devices on final circuits).

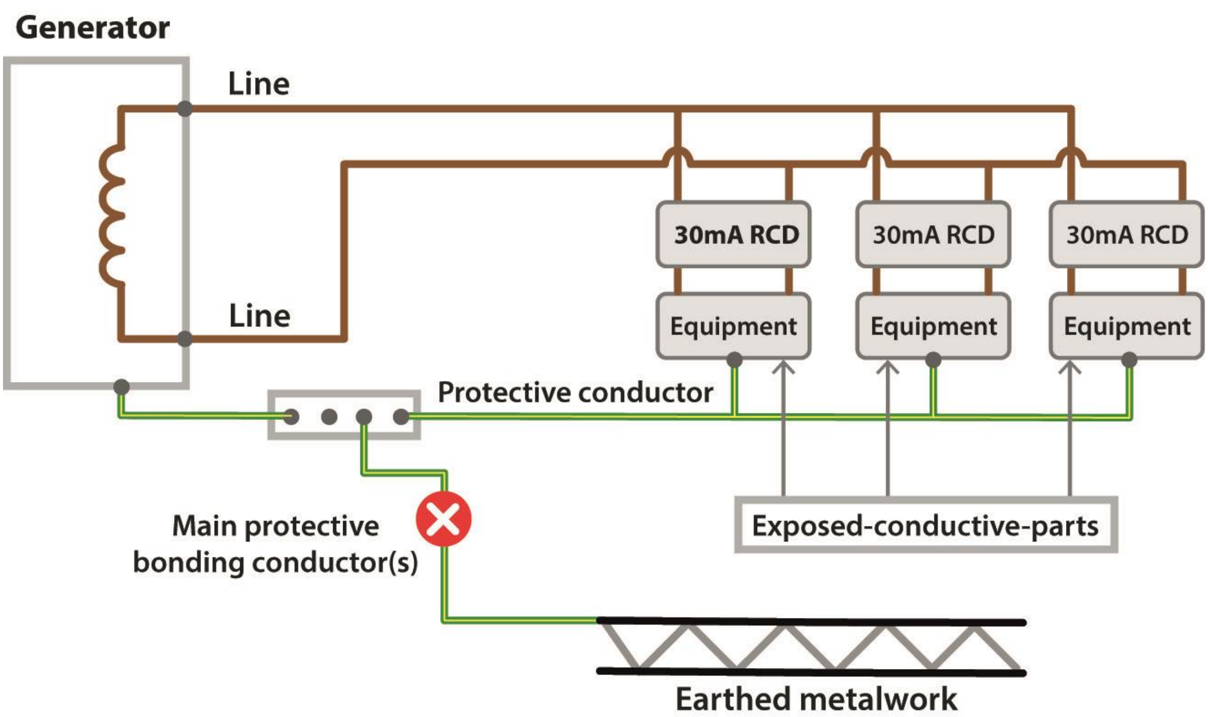
The other requirement of this floating mode is that it is for a short duration. It's a control measure for when there is no other option. If possible, such systems should have an earth electrode; the protection will then be much more reliable, especially in detecting cable faults.

It is also important to think of the temporary distribution connected to the generator when considering the RCD rating. A generator supplying power tools or other final circuits directly would need to have a 30 mA RCD fitted on the output.

If the generator is supplying a distribution unit that has 30 mA RCDs protecting final circuits (such as those fitted in a consumer unit in a portable building), then the supply from the generator is a distribution circuit, not a final circuit, and can be treated as such when considering Regulation 411.3.3 of BS 7671:2018+A1:2020 (see also Note 1 of the same).

The third topology shown in Figure 5 is common with (but not limited to) smaller generating sets of 1 or 2 KVA. The keen-eyed reader will notice that this earthing arrangement is the same as the protective measure *electrical separation*, so Regulation Group 413 of BS 7671:2018+A1:2020 applies.

Figure 5 Generator configured as electrical separation



A notable feature about this arrangement is that an RCD on the output of the generator will serve no purpose – it is the only generator arrangement where this is so. In addition, equipment requiring a connection with earth for functional reasons (for example, for internal filtering or electromagnetic compatibility (EMC) measures, common on many modern power supplies) will not work effectively, as the protective conductor is not connected to the supply. This can lead to a voltage appearing on the casing of the equipment.

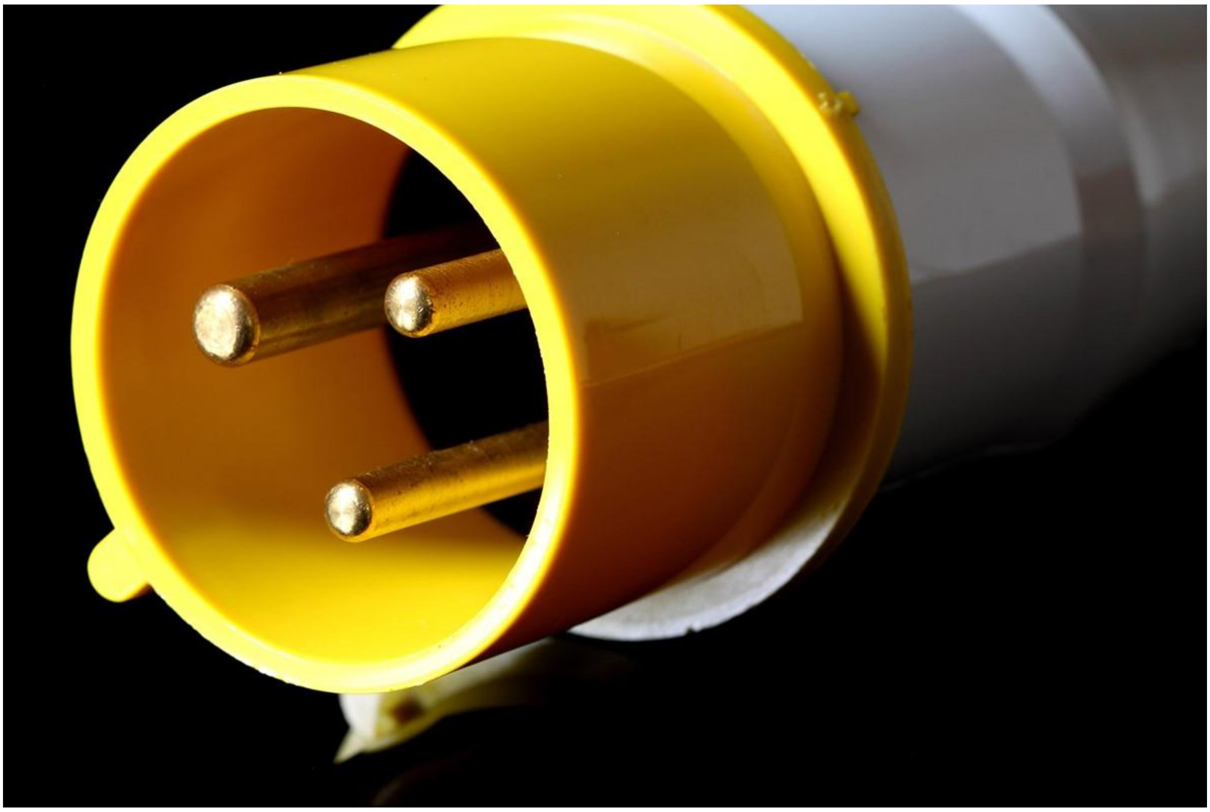
It is also important to ensure that the protective conductor is not connected to the mass of Earth (such as by connecting it to earthed metalwork), as this would turn the arrangement into an IT system (Regulation 411.6 of BS 7671:2018+A1:2020), which has differing requirements for protection, such as insulation monitoring devices (IMDs), for example. In practice, IT systems are difficult to implement as there is a requirement for a reliable earth electrode of known resistance to enable IMDs to function, which is often impractical to achieve for most temporary systems deployed for a short duration.

One aspect of the arrangement in Figure 5 is that a first fault will go undetected with Class I equipment. A fault with one item will cause the protective conductor to rise to (or near) the line voltage. In itself, this is not a problem, as there is no risk of shock, but a second fault on another item of equipment or a distribution cable could present a shock risk. For this reason, each item of Class I equipment must be protected by its own RCD complying with Regulation 415.1 of BS 7671:2018+A1:2020 (such as could be achieved by using socket-outlet RCDs). Regulation Group 418.3 of BS 7671:2018+A1:2020 should also be consulted if more than one item of Class I equipment is used.

In the event of a second fault, one of the RCDs will operate, thereby going back to the first fault condition and hence mitigating the risk. With Class II equipment, a fault does not give rise to the risk of shock and so any number of Class II items of equipment can be connected to the generator.

There is plenty of other related advice on this subject in the IET *Practitioner's Guide*, including advice on cable and RCD selection for such systems, paralleling generator sets (or other supplies), example set-ups and more. It's all new information and is worth being aware of if you deal with any form of temporary power generation. The new guide is available from the IET bookshop.
Section 551 of BS 7671:2018+A1:2020 also has salient advice on this subject, although it should be noted that this is currently being reviewed at an international level. Chapter 55 of BS 7671:2018+A1:2020 is quite detailed in describing alternative supplies and temporary generators. The principles of earthing are largely the same, whether the source is a rotating alternator or an electronic inverter, so this article will hopefully prove useful if you work with such systems.

Finally, note that if you do deploy an earth electrode, it has to be effective. That means that its resistance must be low enough to cause sufficient current to trip the protective device on the output of the generator in the event of a fault to the mass of Earth. This will usually require very low values of earth electrode resistance, which in practice will be hard to achieve; hence RCDs on the output of TN generator topologies can provide much more effective protection. The electrodes in the pictures below will serve no practical purpose for electrical safety….



Reduced Low Voltage systems

By: **Michael Peace CEng MIET**

Everything you need to know about Reduced Low Voltage (RLV) systems.

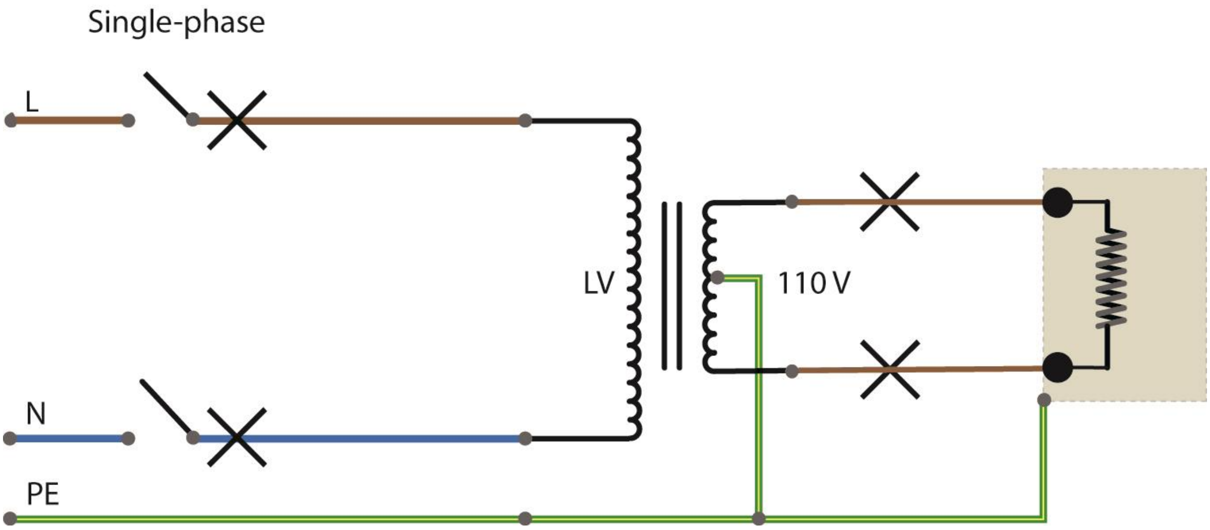
What are Reduced Low Voltage (RLV) systems?

RLV systems are commonly known as 110 V centre-tap earthed systems, defined in BS 7671:2018+A1:2020 as:

A system in which the nominal line-to-line voltage does not exceed 110 volts and the nominal line to Earth voltage does not exceed 63.5 volts.

The benefit of this type of system is the reduced risk of electric shock due to the lower voltage between live conductors and earth. If a person should come into contact with a live part, the maximum touch voltage would be 55 V. Not only does it provide a reduced touch voltage, but it also provides Automatic Disconnection of Supply (ADS).

Figure 1 Typical arrangement of a low voltage (LV) supply and RLV system



Where are RLV systems used?

RLV systems are most commonly used on construction sites and in workshops. Section 704 of BS 7671:2018+A1:2020 details the requirements for construction sites, Regulation 704.410.3.10 (i) recognises RLV as a method of protection.

Regulation 704.410.3.10 (ii) of BS 7671:2018+A1:2020 permits the use of RCDs as a method of protection for a circuit supplying a socket-outlet with a rated current up to 32 A on a construction site. However, the usual approach is to use RLV systems.

Reasons for this include the fact that RLV systems have an impeccable safety record with no fatalities ever recorded, compared with RCDs and the requirement to frequently test them, the associated cost and their susceptibility to damage when installed in a harsh environment. If an RCD fails, a dangerous situation could occur. Transformers are proven to be reliable and have been proven to last for many years without maintenance.

What are the requirements of BS 7671:2018+A1:2020 for RLV systems?

Regulation 411.8 of BS 7671:2018+A1:2020 provides the requirements for RLV systems. The requirements for basic protection in Regulation 411.8.2 include basic insulation and barriers or enclosures, the same as for LV systems.

The requirements for fault protection are provided in Regulation 411.8.3. This can be achieved either with an overcurrent protective device, providing a disconnection time of five seconds can be met, or, if this can't be achieved, by an RCD.

What type of protection is required for RLV circuits?

In theory, under fault conditions, the touch voltage may not exceed 30 V, which would put it in the extra-low voltage (ELV) range, which does not require disconnection. However, disconnection is required to comply with BS 7671:2018+A1:2020 and prevent unwanted thermal effects.

RLV circuits are no different to any other electrical circuit, in that suitable protection must be provided. This includes short-circuit and overcurrent protection, automatic disconnection, consideration of current-carrying capacity and voltage drop, which can be one of the major limiting factors, due to the reduced voltage and increased current, leading to an increase in the required conductor size.

As both conductors are line conductors, at a voltage above earth, all line conductors must be disconnected in the event of a fault. Therefore, a double-pole protective device must be used for single-phase circuits and a triple-pole device for three-phase circuits. It's important to remember that all protective devices must be suitable for use with 110 V – manufacturers can provide guidance on this.

How do I calculate I_{pf} and Z_s values for RLV systems?

It may be necessary to calculate the prospective fault current on the secondary side of the transformer. For this, the formula below can be used:

$$I_{pf} = \frac{55\ \text{V}}{Z_s}$$

How do I measure earth fault loop impedance (Z_s) on RLV circuits?

Some earth fault loop impedance testers provide the functionality required to perform Z_s tests directly. It's important to remember that there is not a neutral conductor on an RLV circuit, but two line conductors and therefore two $R_1 + R_2$, earth fault loop impedance (Z_s) and prospective fault current (I_{pf}) tests will be required, one for each conductor, with the highest value being recorded on the certificate or report.

Unfortunately, not all test equipment has this functionality. However, an alternate method of determining Z_s is by calculation. Note that the Z_s measurement on an RLV circuit will be as far as the RLV transformer, i.e. the secondary winding only; the circuit supplying the RLV transformer will not form part of the earth fault loop impedance measurement.

Can I calculate earth fault loop impedance (Z_s) on RLV circuits?

If required, the earth fault loop impedance can also be calculated using the formula below. For simplicity, this can be broken down into three steps.

$Z_s = Z_p * (V_s/V_p)^2 + Z_{pu} (V_s)^2/VA + (R_1 + R_2)\ \Omega$

Where:

Z_p = the impedance of the primary supply circuit

Z_s = the equivalent secondary impedance

V_p = primary voltage

V_s = secondary voltage

Z_{pu} = the impedance of the transformer

VA = the volt-amp rating of the transformer

R_1 and R_2 = the final circuit line and protective conductor resistance

Step 1: the supply circuit (Z_p)

First, we need the impedance of the line to neutral of the primary circuit, including the external earth fault loop impedance (Z_e): this is called Z_p. This value could be used in the complete calculation or it could be converted to a value that can be put into the transformer secondary (this is called a reflected value because it is being reflected from the primary to the secondary side).

Assuming the Z_e is 0.2 Ω and the circuit supplying the transformer has a line to neutral impedance that is 0.3 Ω, the impedance of the supply at the primary terminals of the transformer is 0.5 Ω. Next, the reflected impedance must be calculated.

$Z_p \times (V_s/V_p)^2$

$0.5 \times (110/240)^2$

$0.5 \times 0.21 = 0.11\ \Omega$

Z_p = **0.11 Ω** (impedance of the supply reflected to the secondary side)

Note that Vs/Vp is the same as N2/N1 (where N is the number of turns on the transformer windings), so you should generally use 110/240 (not 230).

Step 2: the impedance of the transformer (Z_{pu})
Assuming the transformer is rated at 10 kVA, the details of the transformer are known, and the impedance is expressed as a percentage, for this example, 4 %, then:

$Z_{pu} \times V_s^2/VA$

$0.04 \times 110^2/10,000$

$0.04 \times 12,100/10,000$

$0.04 \times 1.21 = 0.05\ \Omega$

Z_{pu} = **0.05 Ω** (transformer impedance)

Step 3: the impedance of the final circuit (R1 + R2)
For this example, the value of R1 + R2 is given as 0.3 Ω.

R1 + R2 = **0.3 Ω** (the resistance value of the secondary circuit).

Z_s at load = 0.11 Ω + 0.05 Ω + 0.3 Ω = **0.19 Ω**

What are the maximum Z_s values for RLV systems?

Table 41.6 of BS 7671:2018+A1:2020 provides maximum earth fault loop impedance values for BS EN 60898 and general-purpose BS 88-2 fuse systems. In practice, it is very difficult to achieve the values in Table 41.6. RLV systems are most commonly used on construction sites, where TT earthing systems are used. These generally have higher earth fault loop impedance, unless specialist earthing systems are designed and installed. This can sometimes be difficult to achieve when using smaller transformers, as they typically have a higher impedance. This can result in the maximum Z_s value being exceeded at the transformer terminals before taking the circuit resistance into account.

It is for this reason that most RLV circuits are protected with a residual-current circuit-breaker (RCCB) or residual-current circuit-breaker with overcurrent protection (RCBO). However, it's important to remember that these must be the correct type and suitable for the voltage range in order to work correctly on RLV systems, or the test button will not work. Most RCBOs that are designed to operate on a 230 V supply are likely to have single-pole thermal and magnetic protection that would be unsuitable for an RLV system.

Figure 2 Table 41.6 of BS 7671:2018+A1:2020: Maximum earth fault loop impedance values

TABLE 41.6 –
Maximum earth fault loop impedance (Z_s) for 5 s disconnection time and U_0 of 55 V (single-phase) and 63.5 V (three-phase)
(see Regulations 411.8.1.2 and 411.8.3)

	Circuit-breakers to BS EN 60898 and the overcurrent characteristics of RCBOs to BS EN 61009-1 Type				General purpose (gG) fuses to BS 88-2 – fuse systems E and G	
	B		C and D			
U_0 (Volts)	55	63.5	55	63.5	55	63.5
Rating amperes	Z_s ohms					
3	3.48	4.02	1.74	2.01		
6	1.74	2.01	0.87	1.01	2.90	3.35
10	1.05	1.21	0.52	0.60	1.63	1.89
16	0.65	0.75	0.33	0.38	0.95	1.10
20	0.52	0.60	0.26	0.30	0.67	0.77
25	0.42	0.48	0.21	0.24	0.52	0.60
					-	-
32	0.33	0.38	0.16	0.19	0.42	0.48
40	0.26	0.30	0.13	0.15	0.31	0.35
50	0.21	0.24	0.10	0.12	0.24	0.27
63	0.17	0.19	0.08	0.10	0.19	0.22
80	0.13	0.15	0.07	0.08	0.13	0.15
100	0.10	0.12	0.05	0.06	0.12	0.14
125	0.08	0.10	0.04	0.05	0.08	0.09
I_n	$10.4/I_n$	$12.1/I_n$	$5.2/I_n$	$6.1/I_n$		

NOTE 1: The circuit loop impedances have been determined using a value for factor C_{min} of 0.95.

NOTE 2: The circuit loop impedances given in the table should not be exceeded when:

(i) the line conductors are at the appropriate maximum permitted operating temperature, as given in Table 52.1, and

(ii) the circuit protective conductors are at the appropriate assumed initial temperature, as given in Tables 54.2 to 54.6.

Are RLV systems expensive to install?

The additional cost for an RLV system is the transformer. However, this cost can quickly be recovered when you consider that using RCDs for protection could be expensive, due to the need to prevent inconvenience or danger in the event of a fault, as identified in Regulation 314.1 of BS 7671:2018+A1:2020. For example, to prevent the whole site from losing power in the event of a single fault, multiple RCDs and circuits would be required, with time-delayed RCDs installed at source (and of course, the correct type of RCD would be important). More information on different RCD types can be found in the *Which RCD Type?* article from Issue 77 of Wiring Matters.

How do I identify the conductors for an RLV system?

It's important to remember that a single-phase RLV circuit does not have a neutral conductor, as there is not an earthed live conductor on the secondary side; however, the centre point of the secondary winding is earthed and the potential between each live conductor and earth is the same, i.e. 55 V. As shown in Figure 3, both line conductors on a single-phase RLV system should be identified by the colour brown or the letter 'L'. Regulation 514.3.1 of BS 7671:2018+A1:2020 states that:

Except where identification is not required by Regulation 514.6, cores of cables shall be identified by:

(i) colour as required by Regulation 514.4 and/or

(ii) letters and/or numbers as required by Regulation 514.5.

Figure 3 Table 51 of BS 7671:2018+A1:2020: Identification of conductors

TABLE 51 – Identification of conductors

Function	Alphanumeric	Colour
Protective conductors		Green-and-yellow
Functional earthing conductor		Cream
AC power circuit (1)		
Line of single-phase circuit	L	Brown
Neutral of single- or three-phase circuit	N	Blue
Line 1 of three-phase AC circuit	L1	Brown
Line 2 of three-phase AC circuit	L2	Black
Line 3 of three-phase AC circuit	L3	Grey

Summary

If, for functional reasons, the use of ELV is impracticable, then in the absence of any requirement for separated extra-low voltage (SELV) or protective extra-low voltage (PELV), RLV systems are a good alternative.

RLV systems are renowned to be a safe system for use in areas with increased risk of electric shock, such as construction sites. They offer increased protection from electric shock, due to the lower touch voltages when compared with an LV system, with the additional protective measure of ADS.

RLV systems are usually installed on construction sites, where the earthing arrangement is likely to be TT. Achieving ADS without the use of RCCBs/RCBOs is difficult, especially with smaller transformers and long cable runs. Due to the reduced voltage compared with a 230 V circuit, the voltage drop will be greater for an RLV circuit: this can limit circuit length and/or increase cable size.

Additional sources of information

BS 7671:2018+A1:2020 The 18th Edition of the IET Wiring Regulations *Requirements for Electrical Installations*

BS 7375:2010 *Code of Practice for distribution of electricity on construction and demolition sites*

BS 4363:1998+A1:2013 *Specification for distribution assemblies for reduced low voltage electricity supplies for construction and building sites*