Chapter 16

Inspection and Testing

16.1 INTRODUCTION

The Purpose of Inspection, Testing and Certification or Reporting

The fundamental reason for inspecting and testing an electrical installation is to determine whether new installation work is safe to be put into service, or an existing installation is safe to remain in service until the next inspection is due.

Required Competence to Undertake Electrical Inspection and Testing

The inspector carrying out the inspection and testing of any electrical installation must have a sound knowledge and experience relevant to the nature of the installation being inspected and tested, and to the technical standards. The inspector must also be fully versed in the inspection and testing procedures and employ suitable testing equipment during the inspection and testing process.

Safety

Electrical testing involves some degree of hazard and before the commencement of any tests, the inspector must take steps to ensure that they work in a safe manner and also consider the safety of others when the test takes place. The safety procedures detailed in health and safety Executive Guidance Note GS38, electrical test equipment for use by electricians, should be observed.

Before any testing takes place the tester should ensure that the meter is within the calibration date and has been checked for ongoing accuracy before use. If the test instrument is not within the calibration date the results obtained will be classified as invalid. The test meter has to be proved accurate before commencement of any testing takes place.

General information and guidance on Safety procedures can be found in IEE Guidance Note 3, Section 1. Inspection and testing of electrical installations are dealt with in Part 6 of the IEE Regulations, Chapters 61, Initial Verification, and 62, Periodic Inspection and Testing. Chapter 63 of the IEE Regulations lays out the recommendations when certifying and reporting on an Electrical Installation.
In this chapter, two aspects will be considered. Firstly, Initial Verification of the installation, followed by Periodic Inspection and Testing. The first of these is covered within IEE Chapter 61. This section covers and recommends procedures in the inspection of new electrical installations.

16.2 INITIAL VERIFICATION

General Procedure

Initial verification, in the context of the IEE Regulations, is covered by Regulation 610, which is intended to confirm that the installation complies with the designer’s intentions and has been constructed, inspected and tested in accordance with BS 7671, the IEE Regulations.

Before the commencement of initial inspection and testing the designer, or the person responsible for the design, must make available the results of the assessment of general characteristics required by IEE Sections 311–313, together with the information required by Regulation 514.9. IEE Regulation 610 Inspection and, where appropriate, testing should be carried out and recorded on suitable schedules progressively throughout the different stages of erection and before the installation is certified and put into service.

The results of the different stages of testing must be compared with the design calculations, so as to determine that the correct installation procedures have taken place and that the design, on completion, will comply with the appropriate mandatory, statutory regulations, British Standards and building regulations.

Inspection

IEE Regulation 611 requires the checking of a number of items in the installation and that where necessary this should be done during erection. These include:

- electrical connections
- identification of conductors
- safe routing of cables
- conductors are selected in accordance with the design
- that single-pole devices are connected in the phase conductor
- correct connection of sockets, accessories and equipment
- presence of fire barriers
- appropriate insulation of conductors
- presence of protective conductors
- appropriate isolators and switches
- methods of protection against electric shock
- prevention of mutual detrimental influence
- undervoltage protection
• danger notices and labelling of circuits, fuses etc.
• access to switchgear is adequate.

Testing

IEE Regulations 612.1–612.14 detail the standard methods of testing required. The tests should be as follows, and should be carried out in the sequence indicated:

1. continuity of protective conductors
2. continuity of final circuit ring conductors
3. insulation resistance
4. insulation of site-built assemblies
5. protection by separation of circuits
6. protection by barriers or enclosures
7. insulation of non-conducting floors and walls
8. polarity
9. earth electrode resistance
10. earth fault loop impedance
11. prospective fault current
12. functional tests including the operation of residual current devices (RCDs).

The methods and recommendations of carrying out the initial inspection and testing of electrical installations are detailed in IEE Regulations Chapter 61 along with guidance on initial inspection and testing.

Most installations will be covered by the test methods described in the IEE Guidance Note 3 Section 2 and the IEE Regulations state the preferred testing methods to be used. If installation concerned does not come into the remit of these publications, guidance on inspection and testing methods must be sought from one of the companies’ qualifying supervisors before commencement of any initial inspection and testing.

The Health and Safety Executive has issued a guide on Electrical Testing, HS (G) 13, which gives advice on precautions which should be taken when testing live installations. The guide mentions that many accidents occur when making these tests. It recommends that bare ends of test probes should not exceed 2–3mm of bare metal, and that metal lampholders should never be used for test lamps.

Some further advice, based upon practical experience, is given here to supplement the advice contained in the Regulations.

Continuity Tests

The requirements for continuity testing are covered in Section 612.2 of the IEE Regulations.
**Test Instrument**

The test instrument to be used for continuity testing is an ohmmeter having a low ohms range, or an insulation and continuity test instrument set to the continuity range. Continuity test readings of less than 1 ohm are common. Therefore, the resistance of the test leads is important, and should not be included in any recorded test results. If the test instrument being used does not have provision for correcting the resistance of the test lead, it will be necessary to measure the resistance of the leads when connected together, and the measured value to be subtracted from all the test results.

**Continuity of Circuit Protective Conductors**

There are two main methods of continuity testing, and these are described below.

**Method 1**

The line conductor is required to be connected to the protective conductor within the distribution board, this commonly achieved by using a bridging strap connected between the line conductor and the relevant earth connection related to the particular circuit. Then with a continuity tester test between the line and earth terminals at each point in the circuit, the measurement at the circuit’s extremity should be recorded, which will be the value of \((R_1 + R_2)\) for the circuit under test.

If the instrument does not include an ‘auto-null’ facility, or this is not used, the resistance of the test leads should be measured and deducted from the final resistance reading of the circuit under test.

**FIGURE 16.1** The test for continuity involves using a bridging strap connected between the line conductor and the relevant earth connection related to the particular circuit, here conveniently applied at a socket outlet.
Method 2
This is commonly known as the long lead test. This test requires the use of a long piece of cable connected to the main earth terminal at source. The other end of the cable is then connected to one side of the continuity meter. The remaining terminal on the continuity is then connected onto the protective conductor at various points on the circuit under test, such as luminaries, switches, spur outlets etc. The results obtained, after the deduction of the resistance of the long lead, are recorded on test certificates under the column of $R_2$.

This particular test may also be utilised to prove the continuity of the main equipotential and extraneous earthing conductors, although if the earthing cables are visible and if it is possible to trace the cable from the origin to the destination, this test may not be required.

Continuity of Ring Final Conductors
There are two methods for testing a ring circuit, which are detailed below.

Method 1
The first test is to prove the continuity of each conductor and to prove that the conductor continues throughout the circuit. This is achieved by testing the continuity of ring final circuit conductors, a digital ohmmeter or multimeter set to ‘ohms’ range should be used. The ends of the ring circuit conductors are separated and the resistance values noted for each of the live conductors and for the protective conductor. The ring circuit is then reconnected and a further resistance measurement taken for each conductor between the distribution board and the appropriate pin of the outlet nearest to the mid-point of the ring. The value obtained should be approximately one quarter of the value of the first reading for each conductor. The test lead needed to carry out the second part of this test will be quite long, and it will be necessary to determine its resistance and deduct the figure from the readings obtained to obtain a valid result.

Method 2
An alternative method of testing a ring circuit avoids the use of a long test lead. It is initially necessary to determine which ends are which for the installed ring circuit. This is done by shorting across the phase and neutral conductors of the first or last socket outlet on the ring, and applying an ohmmeter to the cable ends at the distribution board (see Fig. 16.2a). If the readings of the test meter are different in position A than in position B the pairs are matched correctly and the test may be continued. If the readings are the same in position A and in position B, the short and long sides of the ring are linked, and the wrong pairs have been selected, therefore the test is unacceptable.

The next step is to remove the short circuit from the first or last socket outlet on the ring. Then short together the live conductor of one of the pairs of cables and the neutral conductor of the other; also short together the remaining pair of cables (see Fig. 16.2b).
The test instrument is then connected to each socket outlet on the ring in turn. The resistance reading in each position should be identical, and if it is, the continuity is proved. If one of the readings is different, the socket outlet either is connected as a spur to the ring circuit or is a socket outlet on a different ring.

Special instruments are available for checking the resistance of the CPC or of metal conduit and trunking where it is used as part of the protective conductor. The instrument operates by applying a current at extra-low voltage

FIGURE 16.2 Testing the continuity of a ring circuit as described in the text: (a) indicates the end socket shorted out for the initial test to identify the individual cables; (b) shows part two of the test, applying the ohmmeter to each socket in turn and comparing the resistance readings. All the resistances must be identical to show that continuity is proved.
to the section of conduit or trunking connected and gives a reading of the continuity in ohms. The characteristics of such an instrument are included in IEE Regulation 713-02-01.

**Insulation Resistance**

Insulation tests should be made with an insulation resistance tester, with a scale reading in ohms. The voltage of the instrument should be as detailed within Tables 16.1 and 16.2.

Suitable instruments for making these tests are shown in Figs 16.3–16.5.

The main test should be made before the luminaires and lamps are installed, but with all fuses inserted, all switches on, and the conductors of both poles connected together, and with the supply switched off. This test will be between all conductors bunched, and earth. The result of the test should be not less than 1.0 MΩ. Before the test, particular attention should be given to the presence of electronic devices connected to the installation, and such devices should be isolated so that they are not damaged by the test voltage.

Another test is between phase and neutral conductors, with all lamps removed, and all switches in the ‘on’ position. This test shall produce a reading

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**TABLE 16.1 Minimum Values of Insulation Resistance for Standard Circuits**

<table>
<thead>
<tr>
<th>Circuit nominal voltage (V)</th>
<th>Test voltage (V d.c.)</th>
<th>Minimum insulation resistance (MΩ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SELV and PELV</td>
<td>250</td>
<td>≥0.5</td>
</tr>
<tr>
<td>Up to and including 500V with the exception of SELV and PELV, but including FELV</td>
<td>500</td>
<td>≥1</td>
</tr>
</tbody>
</table>

**TABLE 16.2 Minimum Values of Insulation and Resistance for SELV, PELV and Circuits Above 500V**

<table>
<thead>
<tr>
<th>Circuit nominal voltage (V)</th>
<th>Test voltage (V d.c.)</th>
<th>Minimum insulation resistance (MΩ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SELV and PELV</td>
<td>250</td>
<td>≥ 0.5</td>
</tr>
<tr>
<td>Above 500V</td>
<td>1000</td>
<td>≥ 1</td>
</tr>
</tbody>
</table>

Note: Test voltages to be as follows:
250 V d.c. for extra-low voltage circuits
500 V d.c. for low-voltage circuits up to 500V, and
1000 V d.c. for low-voltage circuits between 500V and 1000V.
of not less than 1.0MΩ. If a reading lower than 1.0MΩ is obtained then steps must be taken to trace and rectify the fault.

Where surge protective devices, electronic equipment or other devices such as RCDs are present, these are likely to influence the results of the test and may suffer damage from the test voltage. Such equipment must be disconnected before carrying out the insulation resistance test.

If it is not reasonably practicable to disconnect electronic related equipment, the recommended test voltage for the type of circuit may be reduced to 250V d.c. but the insulation resistance must be at least 1MΩ.

FIGURE 16.3 Measurement of earth electrode resistance. X – earth electrode under test, disconnected from all other sources of supply; Y – auxiliary earth electrode; Z – second auxiliary earth electrode; Z₁ – alternative position of Z for check measurement; Z₂ – further alternative position of Z for check measurement. If the tests are made at power frequency the source of the current used for the test shall be isolated from the mains supply (e.g. by a double-wound transformer), and in any event the earth electrode X under test shall be disconnected from all sources of supply other than that used for testing.

FIGURE 16.4 A 250/500/1000V insulation and continuity tester, with digital display.
Polarity

The testing for polarity is the same as the check previously carried out earlier in the test sequence. Ring final circuits require a visual check although, as with the radial circuits, the test for ring main circuits was previously carried out when testing the continuity of the circuit.

IEE Regulation 612.6 requires that every fuse and single-pole control and protective device are connected in the line conductor only. It also requires a check that E14 and E27 lampholders, not to BS EN 60238, have the outer or screwed contacts connected to the neutral conductor; but this does not apply to new installations, as new lampholders should be of BS EN 60238 type.

Earth Electrode Resistance

The test should be carried out with a digital earth tester. An alternating current is passed between points X and Y and an additional earth spike Z is placed successively at points Z₁, Z₂ etc. Voltage drops between X and Z, and Z and Y are obtained for successive positions of Z and the earth electrode resistance is calculated and checked from the voltage drop and current flowing.

Earth Fault Loop Impedance

Tests for earth fault loop impedance should be made with an instrument such as that shown in Figs 16.6 and 16.7.

The object of this test (Fig. 16.8) is to ensure that the phase earth loop impedance of the circuit is appropriate to the rating and type of protective device as specified by the IEE Regulations and thus ensure that the circuit will
disconnect within the correct time. If a fault did not result in the fuse or circuit
breaker disconnecting in the correct time, a very dangerous state of affairs
could exist, and it is important that this test be made and acted upon.

Testing Residual Current Circuit Breakers

The operation and use of residual current circuit breakers were described in
Chapter 2. Test instruments can be obtained which are designed to carry out
tests of RCDs and the instrument is connected to the load side of the device, the
loads themselves being disconnected. The test instrument simulates a fault so

FIGURE 16.6  An instrument suitable for use as a digital loop tester is shown here. As with
a number of instruments on the market, it will operate in several modes, easing the work of the tester.

FIGURE 16.7  The same instrument in use for a continuity test.
that a residual current flows, and then measures the response time of the RCD, generally displaying the result in milliseconds. RCDs incorporate an integral test button and the effectiveness of this should also be tested (Fig. 16.9).

The installation of voltage operated earth leakage circuit breakers is not now permitted by the IEE Regulations. However, their use may be encountered in existing installations, and details of a test method suitable for them are given in Fig. 16.10. Voltage operated devices have a number of disadvantages and if any

**FIGURE 16.8** Earth fault loop impedance test measures the impedance in the line-earth loop which comprises the following parts: the circuit protective conductor; the consumer’s earthing terminal and earthing conductor; the earth return path through the general mass of earth; the supply transformer earth; the neutral point of the supply transformer and winding; the phase conductor.

**FIGURE 16.9** This digital instrument is capable of testing RCDs. Devices with ratings from 30mA to 1000mA may be tested.
doubt exists as to their performance, they should be replaced by residual current circuit breakers.

Other tests included in the IEE Regulations are phase rotation tests and nominal voltage tests. These tests clarify that the voltages present are within the required parameters for the type of installation and as recommended within the Electricity Safety, Quality and Continuity Regulations 2002 (ESQCR).

**Alterations and Additions to an Installation**

The relevant requirements of Section 633 of the IEE Regulations apply to alterations and additions to installations. It shall be verified that every alteration or addition complies with the regulations and does not impair the safety of an existing installation.

**16.3 PERIODIC INSPECTION AND TESTING**

**Purpose of Periodic Inspection**

The main purpose of periodic inspection and testing is to detect, so far as is reasonably practicable, and to report on, any factors impairing the safety of an electrical installation.
The aspects to be covered are stated in IEE Regulation 621.2 and include the following:

a. Safety of persons and livestock against the effects of electric shock and burns.
b. Protection against damage to property by fire and heat arising from an installation defect.
c. Confirmation that the installation is not damaged or deteriorated so as to impair safety.
d. Identification of non-compliances with BS 7671 or installation defects which may give rise to danger.

Necessity for Periodic Inspection and Testing

Periodic inspection and testing is necessary because all electrical installations deteriorate due to a number of factors such as damage, wear and tear, corrosion, excessive electrical loading, ageing and environmental influences.

Required Information

It is essential that the inspector knows the extent of the installation to be inspected and any criteria regarding the limit of the inspection, this should be recorded.

Enquiries need to be made with regards to the provision of diagrams, design criteria, electricity supply and earthing arrangements. These will normally be obtained from the person in charge of the installation. Diagrams, charts or tables should be available to indicate the type and composition of circuits, identification of protective devices for shock protection, isolation and switching and a description of the method used for ‘fault protection’ before the commencement of any periodic inspection and testing takes place.

If the required information is not available, then the person carrying out the inspection should make their own assessment of all perimeters of the electrical installation. In this case, on completion of the inspection, an as-fitted drawing of the electrical installation should accompany the Periodic Inspection and Test results.

These records should be retained for further works and inspections, so as to identify any alterations or additions that may occur after the undertaken inspection. If the building facilities manager keeps a building log book the information from the test results may have to be recorded and copied into the appropriate sections of the log book or building manual (Fig. 16.11).

Schedule of Inspection and Testing

No electrical testing should be performed on an installation that does not comply with the current legislation with regards to main, equipotential and supplementary bonding. Testing with the bonding being absent could inadvertently cause any extraneous metal parts or metal parts directly related to the electrical installation to become live. Undertaking the tests in these conditions
may contravene sections of the Electricity at Work Regulations 1989 and the Health and Safety at Work Act 1974, Section 6.

**Frequency of Inspection**

The frequency depends upon the general condition of the electrical installation. If the installation tested is not to standard, then it might be prudent for safety reasons to set the next inspection date for a period less than that indicated in IEE Guidance Note 3, Table 3.3. IEE Table 3.2 which recommends initial frequencies of inspection has been altered to coincide with the recommendations of the report and the IEE Regulations.

**Installations That May Require Periodic Visual Inspection**

If an installation is maintained under a planned maintenance management system which incorporates monitoring and is supervised by a suitably qualified electrical engineer then a formal periodic inspection and test certificate may not be required.

A visual inspection in line with IEE Guidance Note 3, Section 3.5 and page 4 of the NICEIC Periodic Inspection form should record the basic information including:

a. The characteristics of the main device,

b. The earthing arrangements,

c. The size and continuity of equipotential and supplementary bonding conductors,

d. Functional test of RCDs,
e. Functional test of circuit breakers, isolators and switching devices and
f. Earth fault loop impedance values should be sampled and cross-referenced
   with the existing/previous test results for comparison.

The records may be kept on paper or computer and they should record any
electrical maintenance and testing that has been carried out. The results of any
tests should be recorded and the results should be made available for scrutiny.

Unless the circumstances make it unavoidable (for example, if an installer
has ceased trading prior to certifying an installation), a Periodic Inspection
Report should not be issued by one contractor as a substitute for an Electrical
installation Certificate for work carried out by another contractor.

A Periodic Inspection Report does not provide a declaration by the designer
or installer that the aspects of the work for which they were responsible comply
with BS 7671. Also cables that are designed to be concealed cannot be
inspected when construction is complete.

Completion Certificates and Inspection Report Forms

A Completion Certificate and an Inspection Report Form must be provided by
the person responsible for the construction of the installation, or alteration
thereo, or by an authorised person acting for them. Details of these certificates
are given in IEE Regulations Appendix 6. The person who carries out any
installation work assumes a very great responsibility in ensuring that the
certificates are completed and that their terms are complied with in every respect.
Any loss or damage incurred due to any neglect on the part of the person
responsible for the installation might well involve claims for heavy damages.

Notice of Re-inspection and Testing

IEE Regulation 514.12.1 states that a notice, of such durable material as to be
likely to remain easily legible throughout the life of the installation, shall be
fixed in a prominent position at or near the main distribution board on
completion of the work. It shall be inscribed as detailed within the regulation, in
characters not smaller than those illustrated in Fig. 16.12.

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IMPORTANT

This installation should be periodically inspected and tested
and a report on its condition obtained, as prescribed in BS 7671
Requirements for Electrical Installations published by the
Institution of Electrical Engineers.

Date of last inspection .........................

Recommended date of next inspection ............
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**FIGURE 16.12**  Wording specified by the IEE Regulations for the periodic inspection notice.
The determination of the frequency of periodic inspection is covered by IEE Regulation 622. No specific period is laid down, and an assessment needs to be made as to the use of the installation, the likely frequency of maintenance, and the possible external influences likely to be encountered. The person carrying out the inspection and testing, and completing the inspection certificate needs to take account of these issues. In the absence of other local or national regulations, a maximum period of five years would be applied, with shorter periods where appropriate.

All inspection and testing and the final results are required to be signed by a qualifying supervisor.

**Roles of a Qualifying Supervisor**

The qualifying supervisor must ensure, without any doubt, that before they sign an electrical installation certificate that the electrical installation complies with the building regulations, British Standards and the IEE Regulations.

The qualifying supervisor, so as to ensure without any doubt that the electrical installation being undertaken complies with the appropriate legislation, is advised to visit the site where the electrical installation is being undertaken.

The qualifying supervisor is advised to inspect the electrical installation at various stages, including:

a. During the installation of containment and cabling,

b. During the period of dead testing \((R_1 + R_2 \text{ etc.})\),

c. During second fix of electrical items (socket outlets and accessories etc.)

and
d. At the completion of the electrical installation so as to verify final live testing.

The qualifying supervisor at each stage is advised to communicate with the electrical designer so as to compare and discuss the results obtained and/or problems that may have occurred during the erection of the electrical services in question.

By using this method it may well quicken the process of finalising the project and help to solve any installation queries, ensuring that the electrical installation complies with current legislation before completion of the project. It is essential that the qualifying supervisor communicates with the contracts engineer and design engineer responsible for the project before, during and on completion of the project.

Once the qualifying engineer is satisfied that the installation complies with current legislation, the electrical certificate may be signed. A copy of the certificate must then be kept in a safe place with relevant information on the project undertaken including the periodic report notes of the qualifying supervisor during subsequent visits. The certificates must be made available
throughout the year for perusal and inspection upon visits from the relevant inspection body, i.e. NICEIC and/or ECA.

Certificates

All certificates must be logged into the system before they can be distributed to the project engineers, each engineer is required to sign for the particular electrical installation certificate or book.