Electrical Installations: inspection, testing and commissioning

Handout 8: Insulation resistance

Insulation resistance

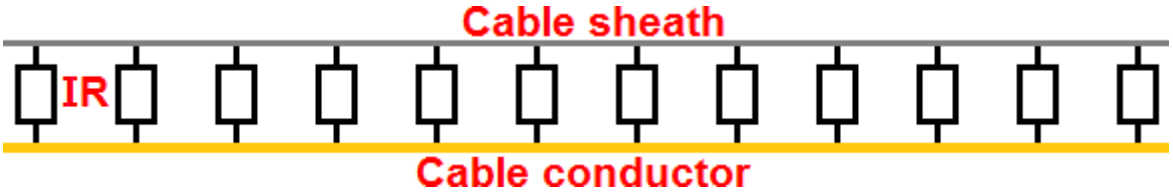
As soon as a cable is manufactured its insulation starts to age. As it ages, its insulating properties will progressively deteriorate. If cables are installed in harsh environments, especially those with temperature extremes and/or chemical contamination, the aging will accelerate. This deterioration can result in dangerous conditions relating to power reliability and personnel safety. As such, it's important to identify this deterioration quickly, so that corrective steps can be taken; this is why we carry out insulation resistance testing.

Factors that affect insulation resistance values

There are two main factors that affect the insulation resistance:

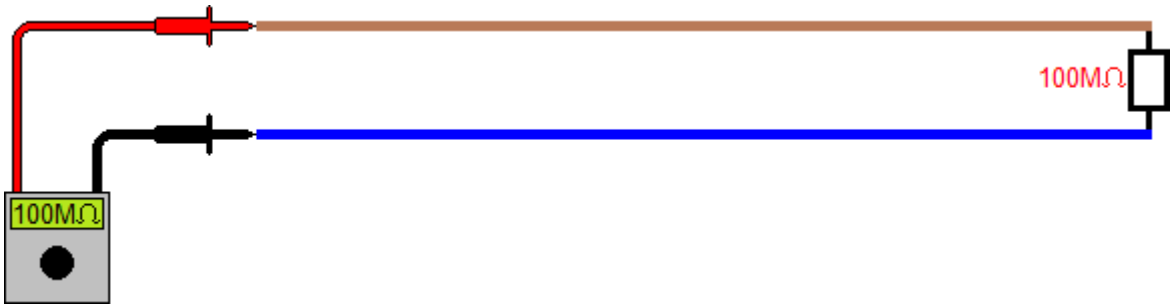
- length
- parallel circuits.

Length: The insulation resistance of a length of cable is the resultant of a number of small individual leakage paths or resistances between the conductor and the cable insulation. These leakage paths are distributed along the cable. Hence, the longer the cable the greater the number of leakage paths, and the lower the insulation resistance.

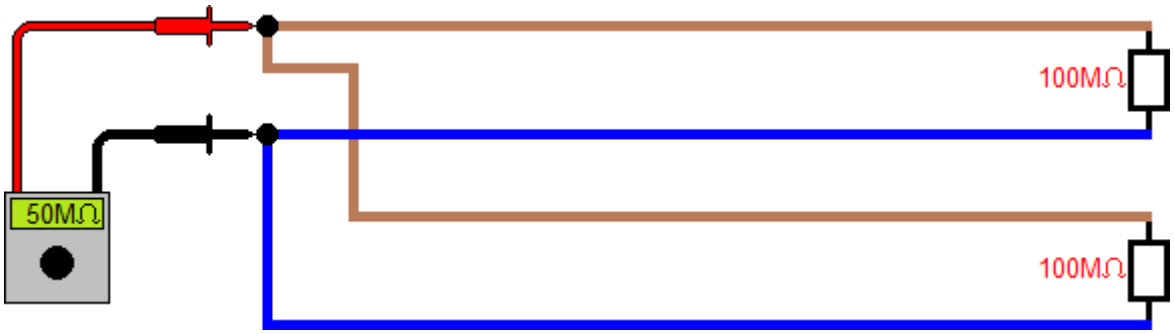


This is because each resistance, although very high in value, is in parallel with the others. As you will remember from electrical science, the more resistors connected in parallel the lower the total resistance.

Parallel circuits: If two final circuits have a L-N insulation resistance of, say, 100MΩ each and an insulation resistance test is carried out on each individually, the reading will obviously be 100MΩ for each circuit.



If the two final circuits are connected together in parallel, as they would be in a consumer unit/distribution board, their combined insulation will be less than that for one circuit; in this case 50MΩ.



The more circuits connected to the consumer unit/distribution board the lower will be the insulation resistance.

This is not usually a problem with domestic and small to medium commercial and industrial premises, but with large premises where there are hundreds or even thousands of final circuits, the insulation resistance reading can be very low, even below the minimum value stated in the Regulations. In this case the installation can be split into sections normally of 50 circuits with each section being tested separately. The following example shows how combining circuits reduces the insulation resistance.

Example: A small domestic installation has six circuits connected into the consumer unit as follows: Cooker (Ins res – 150MΩ), Immersion heater (Ins res – 160MΩ), ring 1 (Ins res – 180MΩ), ring 2 (Ins res – 170MΩ), lighting 1 (Ins res – 140MΩ) and lighting 2 (Ins res – 120MΩ). Calculate the overall insulation resistance.

$$\frac{1}{R_{ins}} = \frac{1}{R_{cct1}} + \frac{1}{R_{cct2}} + \frac{1}{R_{cct3}} + \frac{1}{R_{cct4}} + \frac{1}{R_{cct5}} + \frac{1}{R_{cct6}}$$

$$\frac{1}{R_{ins}} = \frac{1}{150} + \frac{1}{160} + \frac{1}{180} + \frac{1}{170} + \frac{1}{140} + \frac{1}{120}$$

$$\frac{1}{R_{ins}} = \frac{5712 + 5355 + 4760 + 5040 + 6120 + 7140}{856\,800}$$

$$\frac{1}{R_{ins}} = \frac{34\,127}{856\,800}$$

$$R_{ins} = \frac{856\,800}{34\,127}$$

$$= \mathbf{25.1M\Omega}$$

Insulation resistance tests

Insulation resistance testing is a fundamental test for inspectors.

BS 7671:2018 requires that “The insulation resistance shall be measured between live conductors and between live conductors and the protective conductor connected to the earthing arrangement”.

These tests are to verify that the insulation of conductors provides adequate insulation, is not damaged and that live conductors or protective conductors are not short-circuited.

Type of test instrument

An insulation resistance tester should be used, which is capable of providing a DC voltage, as specified in Table 64 below. This Table also specifies the minimum permitted value of insulation resistance.

BS 7671:2018 Table 64: Minimum values of insulation resistance

Circuit nominal voltage (V)	Test voltage DC (V)	Minimum insulation resistance (MΩ)
SELV and PELV	250	0.5
Up to and including 500V with the exception of the above systems	500	1.0
Above 500V	1000	1.0

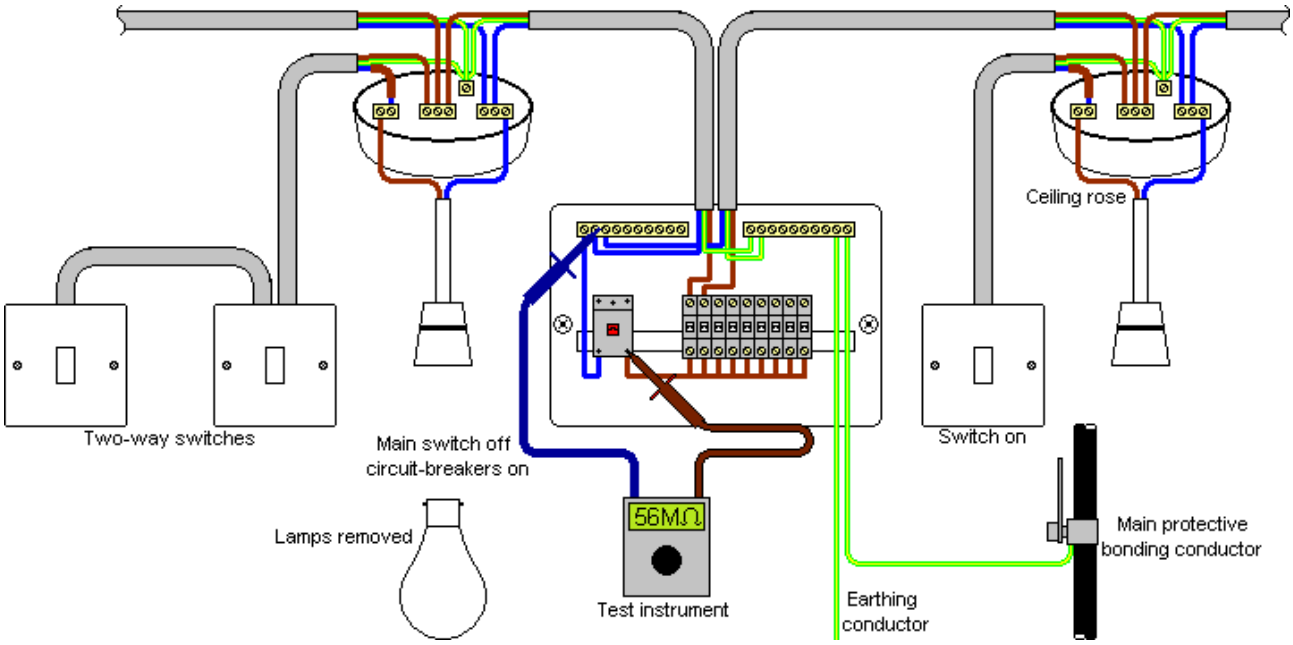
Pre-test checks

Before commencing with insulation resistance tests, a number of checks should be made, with precautions taken as follows:

- that the protective conductor of an item (switchgear or cable, etc) is connected to the main earthing terminal
- that pilot or indicator lamps, and capacitors are disconnected from circuits to avoid an inaccurate test value being obtained
- that voltage-sensitive electronic equipment such as dimmer switches, touch switches, delay timers, power controllers, electronic starters for fluorescent lamps, emergency lighting, RCDs and similar equipment are disconnected so that they are not subjected to the test voltage.

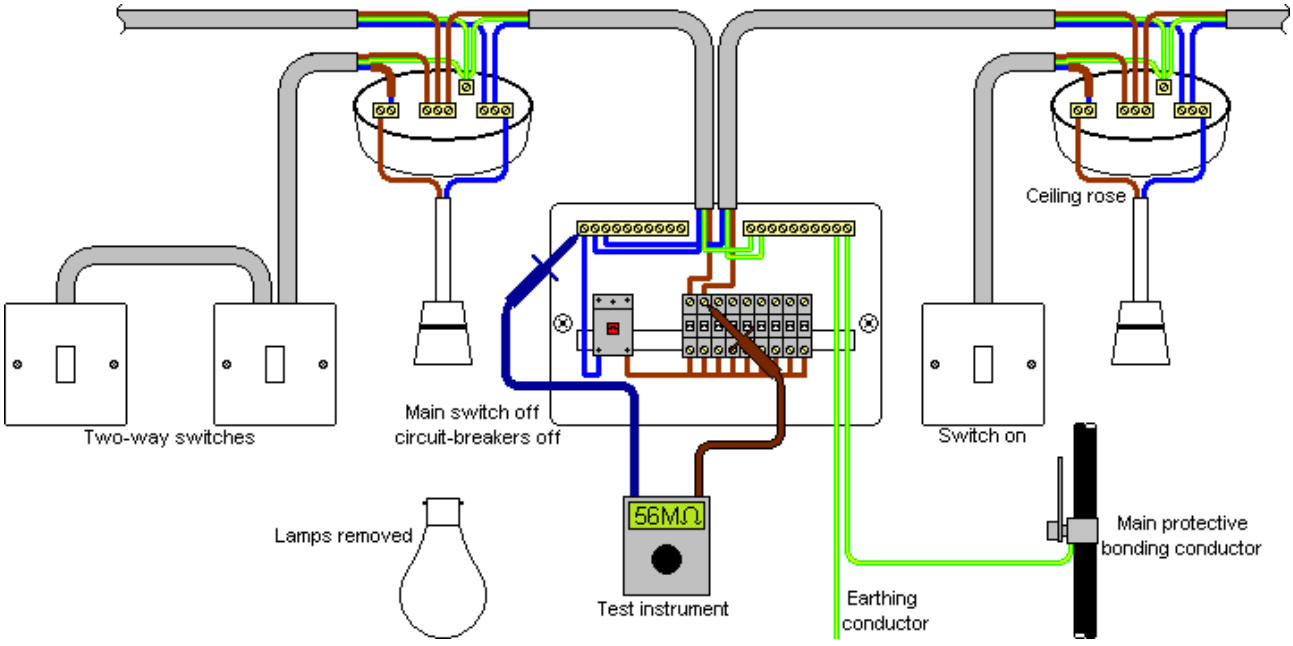
The tests should be carried out with the main switch off, all fuses in place, switches and circuit-breakers closed, lamps removed, and fluorescent and discharge luminaires and other equipment disconnected. Where the removal of lamps and/or the disconnection of current-using equipment are impracticable, the local switches controlling such lamps and/or equipment should be open.

Insulation resistance test of the whole consumer unit.



Where a circuit contains two-way switching, the two-way switches must be operated one at a time and further insulation resistance tests carried out to ensure that all the circuit wiring is tested. This diagram shows the insulation resistance test **Line to Neutral**; further tests required are **Line to Earth** and **Neutral to Earth** making three tests in total.

Insulation resistance test of a final circuit.



Notes:

a) The test may initially be carried out on the completed installation.

b) Earthing and bonding connections are in place.

For an installation operating at 230/400V, although an insulation resistance value of only 1MΩ complies with BS 7671:2018, where an insulation resistance of less than, say, 2MΩ is obtained, the possibility of a latent defect exists. In these circumstances, each circuit should be tested separately.

For a circuit containing two-way switching or two-way and intermediate switching, the switches must be operated one at a time and the circuit subjected to additional insulation resistance tests.

For circuits/equipment vulnerable to the test voltage, the test is made with the line and neutral conductors connected together and earth. It is essential that the incoming earth connection is connected to the installation main earthing terminal (and that this is connected to the means of earthing) for these tests.

For a three-phase board the following tests must be carried out:

Table 2.3 (Guidance Note 3)

Test 1	L1 to L2	The lowest value of these tests is recorded as 'between live conductors'
Test 2	L1 to L3	
Test 3	L2 to L3	
Test 4	L1 + L2 + L3 (connected together) to neutral	
Test 5	L1 + L2 + L3 (connected together) to earth)	The lowest value of these tests is recorded as 'between live conductors and earth'
Test 6	neutral to earth	

Note: It is essential for test 5 and 6 that the cable earth is connected to the installation earthing terminal.