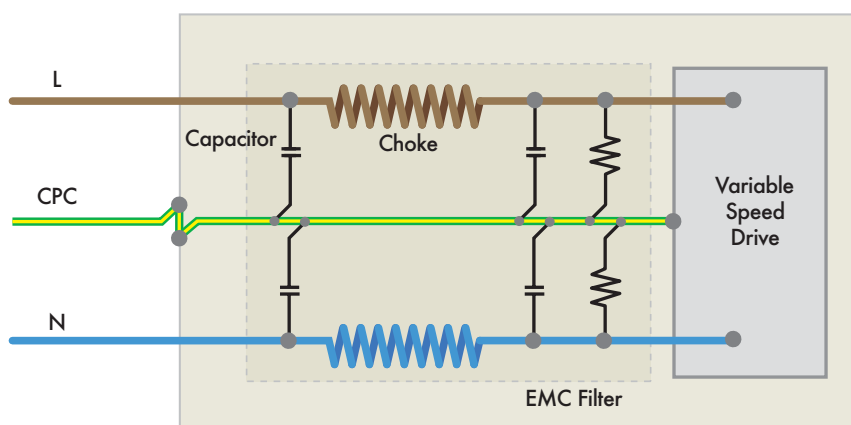


# PAT TESTING OF EQUIPMENT HAVING HIGH PROTECTIVE CONDUCTIVE ('LEAKAGE') CURRENT

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## ELECTRICAL EQUIPMENT

employing small Variable Speed Drives (VSDs) is reducing in cost and size and is appearing more frequently in equipment for non-industrial use. Examples include fitness machines for use in gymnasiums and potters' wheels used in schools and colleges. The installation of such equipment often falls under the jurisdiction of Local Authorities, who, in many cases, have a standing policy that all items of electrical equipment are subject to Portable Appliance Testing (PAT) before being put into service and annually thereafter. VSDs are fitted with EMC filters, (see fig 1) and, often, there is a significant current flow (around 6 mA) through the filters to earth, under normal conditions. This can be indicated as a failure during an earth leakage current measurement performed as part of a portable appliance test, although it is a normal characteristic of the equipment. Regulation 4(2) of the Electricity at Work Regulations 1989 (EWR) requires that:

**Fig 1: Protective conductor current due to EMC filter**

"As may be necessary to prevent danger, all systems shall be maintained so as to prevent, so far as is reasonably practicable, such danger."

There is no specific requirement in legislation detailing that in-service maintenance consisting of inspecting or testing equipment must be performed on an annual basis. However the IEE gives guidance in its publication the 'Code of Practice for In-service Inspection and Testing of Electrical Equipment' that a system of maintenance including performing such testing on a routine basis may achieve compliance with Regulation 4(2) of the EWR. The Code of Practice makes it clear that inspection and testing alone will not result in compliance with the law. The requirement is to maintain electrical equipment as necessary to prevent danger. This means that the requirements of the Electricity at Work Regulations are not met simply by carrying out tests on equipment – the aim is to ensure that equipment is maintained in a safe condition.

Paragraph 15.3 of the IEE's guidance is entitled 'In-service tests' and proposes that in-service testing should be preceded by a preliminary inspection, as described in paragraph 15.1 and summarised in table 1 (see p16).

Testing should then be performed and the Code recommends that three tests are made; Earth continuity, insulation resistance and functionality.

**Table 1: Preliminary inspection**

1	Disconnection	Determine whether the equipment can be disconnected from the supply and disconnect if, and only if, permission is received. If permission is not received to disconnect the supply do not proceed with any tests and record that the equipment has not been inspected and label accordingly
2	Visual inspection	
	Appliance	Thoroughly inspect the equipment for signs of damage. Paragraph 14.5 of the Code of Practice gives full details
	Cable	Inspect the connecting cable for damage throughout its length. Look for cuts, nicks, and kinks. If damage has been repaired with insulating tape, the cable should be replaced. Ensure the cable is routed where it will not suffer damage in use
	Plug	Inspect the plug and check that the plug is suitable for the application. For 13 A applications, a resilient plug marked BS 1363A may be necessary if the plug is subjected to harsh treatment
	Socket-outlet or flex outlet	Inspect the socket-outlet or flex outlet of the fixed wiring system for any signs of damage such as cracks and overheating such as discoloration
3	Assessment	Assess if the equipment is suitable for the environment

**Table 2: Testing**

1	Earth continuity test	Earth continuity testing can only be applied to Class I equipment or cables. Paragraph 15.4 of the Code of Practice gives further details of the testing
2	Insulation resistance test	For many types of appliance, insulation resistance is generally checked by applying a test voltage and measuring the resistance. This test may not always be suitable and the protective conductor/touch current measurement of paragraph 15.6 of the Code of Practice may be a more appropriate alternative
3	Functional check	In its simplest form a functional check is a check to ensure that the appliance is working properly

Note that some electrical test devices apply tests that are inappropriate and may even damage equipment containing electronic circuits, such as VSDs, possibly causing degradation of safety. In particular, while the Code of Practice includes insulation resistance tests, equipment should not be subjected to dielectric strength testing (known as hi-pot testing or flash testing) because this may damage insulation and may also indirectly damage low voltage electronic circuits unless appropriate precautions are taken.

The limit stated in the Code of Practice for insulation resistance for Class I equipment when tested at 500V d.c. is 1 megohm. An item of equipment without input filters generally has an insulation resistance greater than 50 megohm and the use of the insulation test in preference to the leakage current measurement will therefore allow the equipment to be

put into service safely.

Looking in detail at the insulation resistance test, for some types of equipment it may not be appropriate to perform an insulation test at 500 V d.c. because of the risk of damage to the electronic components in the equipment. The testing engineer may then decide to perform the protective conductor/touch current measurement, which is an alternative to the in-service insulation test for use if the insulation resistance test either cannot be carried out or gives suspect test results. The protective conductor current test consists of measuring the current flowing from live parts to earth for Class I equipment, or from live parts to accessible surfaces of Class II equipment.

For practical purposes the test voltage is the supply voltage and the current should be measured within five seconds after the application of the test voltage, the supply voltage, and should not exceed the

**Table 3: Maximum permissible protective conductor current**

Appliance Class	Maximum Current note (1)
Portable or hand-held Class I Equipment	0.75 mA
Class I heating appliances	0.75 mA or 0.75 mA per kW, whichever is the greater, with a maximum of 5 mA
Other Class I equipment	3.5 mA
Class II equipment	0.25 mA
Class III equipment	0.5 mA

Notes to Table 3:

- The values specified above are doubled:
  - if the appliance has no control device other than a thermal cut-out, a thermostat without an "off" position or an energy regulator without an 'off' position.
  - if all control devices have an "off" position with a contact opening of at least 3 mm and disconnection in each pole.
- Equipment with a protective conductor current designed to exceed 3.5 mA shall comply with the requirements of paragraph 15.12.
- The nominal test voltage is:
  - 1.06 times rated voltage, or 1.06 times the upper limit of the rated voltage range, for appliances for d.c. only, for single-phase appliances and for three-phase appliances which are also suitable for single-phase supply, if the rated voltage or the upper limit of the rated voltage range does not exceed 250V;
  - 1.06 times rated line voltage divided by 1.73, or 1.06 times the upper limit of the rated voltage range divided by 1.73 for other three-phase appliances.

**Table 4: Additional requirements for equipment having higher leakage current**

Permanently wired or supplied by an industrial plug and socket-outlet	The equipment shall be permanently wired to the fixed installation, or be supplied by an industrial plug and socket to BS EN 60309-2 (BS 4343)
Protective conductors	The equipment should have internal protective conductors of not less than 1.0 mm <sup>2</sup> cross-sectional area (based on clause 5.2.5 of BS EN 60950), and
Label	The equipment should have a label bearing the following warning or similar wording fixed adjacent to the equipment primary power connection (based on clause 5.1.7 of BS EN 60950)

**WARNING**  
**HIGH LEAKAGE CURRENT**  
Earth connection essential  
before connecting the supply

values indicated in table 3.

However, equipment employing a VSD will, in most cases, have a leakage current greater than 3.5mA due to the filters at the input and hence will be unsuccessful when performing this test. Although this does not show the equipment to be unsafe if this test is performed, the value of current should be recorded since an increased current in any future tests can be due to deterioration of components within the equipment.

The engineer performing the tests will then have to decide if the equipment is still safe for service and will make his judgement based on whether the protective conductor current increased from the previously recorded value or from the manufacturer's advised maximum current. The engineer must then verify that such equipment with a protective conductor current designed to exceed 3.5mA complies

with the requirements shown in table 4.

Further precautions need to be taken for equipment with a protective conductor current exceeding 10mA, see Section 607 of BS 7671.

When appliances have high protective conductor currents, substantial electric shocks can be received from exposed-conductive-parts and/or the earth terminal if the appliance is not earthed. It is most important that appliances with such high protective conductor currents are properly connected with earth before any supply is connected.

Connection to the mains supply via a portable cord set which does not meet EN 60309-2, such as a 13A plug and socket-outlet, is therefore not acceptable. The supply connection to the fixed installation will need to be made using a fused spur connection unit to BS 1363-4, or a plug and socket-outlet in accordance with BS EN 60309-2 and BS 7671. ■