INSPECTION OF ELECTRICAL INSTALLATIONS IN HOMES

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PRESENT SITUATION

Europe has an ageing housing stock. There are many homes with outdated wiring. This wiring is deteriorating, has been inappropriately amended, or is insufficient for the electrical loads of today's typical household. Many of the homes have not undergone any renovation of the electrical installation even though the use of electricity in these homes has been steadily increasing over the past forty years.

Fortunately, the practice of periodically inspecting electrical installations is growing rapidly.

In this paper, we will focus on such inspections and emphasize the importance of carrying out measurements as well as visual inspections.

WHY INSPECTION?

It is hard to imagine homes without electrical installations. However, electricity in homes introduces two major hazards: **fire** and **electric shock**. Electrical defects are one of the most common causes of home fires. Electrical fires in residential buildings result in more damage and higher death rates on average than nonelectrical fires.

Various studies have shown that the costs associated with electrical fires in residential buildings are much higher than the costs associated with electrical shocks casualties.

To counteract these hazards, authorities and standardization bodies have drawn up wiring rules that apply to the design and the erection of electrical installations. However, there is no point in setting rules if it is not *verified* that they have been followed and an adequate level of electrical safety obtained.

The largest portion of domestic electrical installations in Europe were built more than thirty years ago and do not comply with the present safety standards. It is therefore important that all *existing* installations are inspected periodically.

DEFINITIONS

Throughout this document, we will use the following definitions, as given in the IEC 60364-6 'Low-voltage installations — Part 6: Verifications'

***Verification**: all measures which check the compliance of an electrical installation with the relevant requirements.*

***Inspection**: examination of an electrical installation using all available means to ascertain correct selection and proper erection of electrical equipment.*

Note: the word 'inspection' has replaced 'visual inspection', indicating that all of the senses (touch, hearing, and smell, as well as sight) must be used.

***Testing**: implementation of measures in an electrical installation by which its effectiveness is proved.*

***Maintenance**: combination of all technical and administrative actions, including supervision actions, intended to retain an item in, or restore it to, a state in which it can perform a required function.*

INITIAL AND PERIODIC VERIFICATION

A distinction is made between initial and periodic verification.

INITIAL VERIFICATION

An initial verification takes place upon completion of a new installation or upon completion of additions or alterations to existing installations.

The aim of the **initial verification** is to determine whether the requirements of all the applicable prescriptions have been met. This is achieved by *inspection* and *testing*.

Before testing begins, it is important that a full **inspection** of the complete installation is carried out. This is to confirm that the electrical equipment and materials:

- are in compliance with the safety requirements of the relevant equipment standards
- have been correctly selected and erected according to the relevant rules and regulations and to the manufacturer's instructions, in order that performance is not adversely affected
- are not visibly damaged so as to impair safety
- are suitable for the prevailing environmental conditions

This is accomplished by checking:

- the method of protection against electric shock
- the protection against thermal effects
- the precautions against propagation of fire
- the selection of the conductors for current-carrying capacity and voltage drop
- the choice and settings of the protective devices, the presence and correct location of suitable isolating and switching devices
- the selection of equipment and protective measures appropriate to external influences
- the correct identification of the circuits, overcurrent protective devices, switches, terminals, et cetera
- the presence of diagrams, warning notices, or similar information
- the adequacy of the conductor connections
- the presence and adequacy of protective conductors, including equipotential bonding
- the accessibility of the equipment for convenience of operation, identification, and maintenance

In practice, this means checking the following items:

- good workmanship
- separate circuits
- adequate number of circuits
- adequate number of socket-outlets
- all circuits suitably identified
- a suitable main switch provided
- main breakers to interrupt all live conductors
- main earthing terminal provided
- correct fuses or circuit breakers installed
- all connections secure
- the installation earthed in accordance with national standards
- primary equipotential bonding connects services and other extraneous conductive parts to the primary earth facility
- supplementary bonding has been provided in all bath and shower rooms

The following items must checked concerning protection against direct contact:

- insulation of live parts
- enclosures have a suitable degree of protection appropriate to external influences
- enclosures have cable entries correctly sealed
- enclosures have unused entries blanked off where necessary

After inspection, the following tests shall be carried out:

- continuity of conductors
- insulation resistance of the electrical installation
- protection by SELV, PELV, or by electrical separation
- automatic disconnection of supply
- measurement of the resistance of the earth electrode
- measurement of the fault loop impedance
- polarity, functional, and operational tests
- voltage drop

When the results of the initial verification are positive, the electrical installation is in a good condition. However, periodic verification will be necessary to verify that the installation remains in good condition.

PERIODIC VERIFICATION

It is true that electrical installations do not deteriorate quickly and therefore do not usually require high levels of maintenance. However they do not retain their original condition: damage, corrosion, degradation of material, and degradation of the insulation (the insulation hardens and it can crack) all occur. In addition, contacts can become loose as well as excessive electrical loading, ageing, environmental influences, normal wear and tear, and other factors can affect the condition of an installation.

Apart from the deterioration over the years, the functioning of electrical installations does not necessarily follow the changing needs of its users:

- More power sockets are needed. (A recent survey in the UK reveals that two-thirds of Britons say that they don't' have enough plug sockets in their homes!)
- More lighting points are needed

There is an increased awareness of safety, therefore:

- There is a need for an earthing arrangement
- There is a need for RCDs (Residual Current Devices)

Electrical installations should be maintained in a good and safe condition to prevent danger. Part of this maintenance should be a regular verification that includes appropriate inspection and testing.

A periodic inspection is an inspection of the condition of an existing electrical installation to identify — in order of priority — any deficiencies related to the safety standards for electrical installations. Periodic inspections should comprise a detailed examination of the installation. They can be carried out without dismantling or with partial dismantling of the electrical installation.

A periodic inspection will reveal if any of the electrical circuits are overloaded as well as other potential electrical shock risks and fire hazards in the electrical installation.

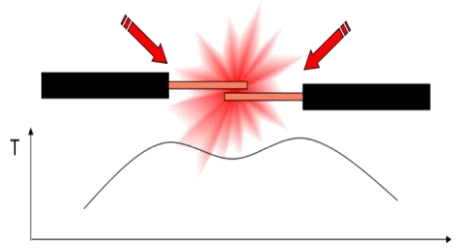
By using a simple, inexpensive system of looking for visible signs of damage or faults, some of the electrical risks can be controlled. Nevertheless, this will need to be backed up by testing.

IS A PERIODIC INSPECTION NEEDED?

Every installation deteriorates with use and age. Therefore, one must ensure that the safety of users is not put at risk and that the installation remains in a safe and serviceable condition.

Let's have a closer look at the principal parts of the installation that play an important role in the safety of an existing electrical installation.

CONTACTS



In case of a bad contact, the resistance of the contact increases, causing a temperature rise. When this happens on a small surface, there is a limited heat drain and the temperature rises even more. Soon the insulation or other materials in the vicinity will lose their properties and a fire can occur.

One study demonstrated that a bad contact of 0.5 ohm rose to 1 ohm after one week and to 10 ohm after one year.

The tables below give a good indication of the amount of heat generated by bad contacts compared to contacts in good condition.

Values with a good connection:

Current **A**	**Voltage drop** **mV**	**Heat developed** **mW**
20	4 — 10	80 — 200
15	3 — 8	45 — 120
10	2 — 5	20 — 50
5	1 — 3	5 — 15
0.8	0.15 — 0,4	0.1 — 0.3

Values with a bad connection:

Current **A**	**Voltage drop** **mV**	**Heat developed** **mW**
20	1,000 — 2,000	20,000 — 40,000
15	1,200 — 1,400	18,000 — 36,000
10	1,500 — 3,000	15,000 — 30,000
5	2,000 — 4,000	10,000 — 20,000
0,8	4,000 —7,000	3,000 — 5,000

One of the best methods of verifying this condition, and even visualising it, is to carry out thermographic controls. Thermography is a non-contact method for measuring temperature based on the fact that every body emits electromagnetic radiation.

WIRING

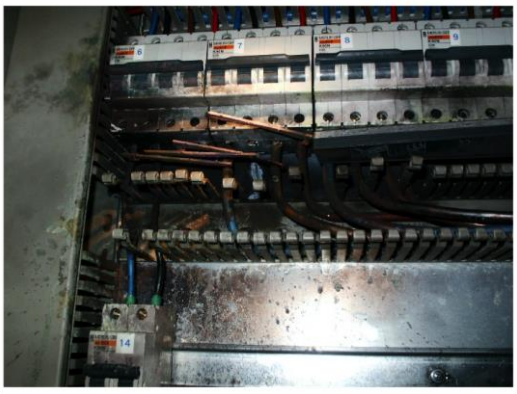
There are two types of risks involving wiring:

- external exposure of the cable to a fire originating in other combustible materials. The cables consist primarily of insulation material (70%), which means that there is a lot of combustible material available
- internal overheating due to overloads or short circuits in cables

There are over 9,000 electrical fires across the UK each year. More than a third of these fires are caused by inadequate or faulty wiring. A periodic inspection and testing of cable condition could be a lifesaver.

An American study revealed that the leading first ignited item in residential electrical fires is the insulation around electrical wires and cables (30.2%). The study showed that 38% of all deaths from fires in residential buildings came from insulation around electrical wires. In most cases, the fires caused by defective or worn insulation were closely related to old electrical wiring.

Arcs caused by short circuits due to defective or worn insulation or from faulty, loose, or broken conductors or switches can initiate fires.



Aluminium wiring poses additional hazards. High temperatures that can lead to fires develop on failing circuits and bad connections. Studies have shown that aluminium-wired connections in homes have a very high probability of overheating compared to copper-wired homes. A large number of connection burnouts have occurred in aluminium-wired homes. The resulting fires involved many injuries and deaths.

WHEN IS A PERIODIC INSPECTION NEEDED?

It is generally accepted that an electrical installation should be inspected every ten years. The ten-year interval is also noted in the IEC 60364. Unfortunately, the periodic inspection is not compulsory in all countries.

When a circuit breaker trips frequently, or sockets, switches, or fuse panels become hot or display burn marks, an inspection and further maintenance is required.

Another occasion to carry out a periodic inspection is when modifications are made to old or existing installations. Structural changes, or changes in the use of an installation, can impair the safety of the installation. In Belgium, an inspection of the electrical installation is required when there is a change of ownership.

WHAT TO INSPECT?

A periodic verification will primarily take into account the following:

- adequacy of the earthing and bonding
- suitability of the switch gear and control gear
- serviceability of the equipment (switches, socket outlets, light fittings) by careful examination for signs of overheating
- the wiring system and its condition (old types of cables, insulation of the cables)
- provision for RCDs
- presence of adequate identification and notices
- extent of any wear and tear, damage, or other indications
- changes in the use of the premises that can lead to deficiencies in the installation

As with the initial verification, it is necessary to carry out inspection, tests, and measurements. The measurements will give a good indication of the status of the electrical installation and particularly of the cables and contacts.

Some tests will have to be carried out without the supply connected, while others can only be performed with the installation energized.

Some of the tests that can be carried out with the supply connected:

- continuity of the protective conductors
- equipotential bonding
- earth electrode resistance
- earth-fault loop impedance
- correct operation of the RCDs
- correct operation of switches and isolators

Considering the importance of cables and contacts in an electrical installation, testing of their condition requires that tests to be carried out without the supply connected.

HOW TO TEST THE QUALITY OF THE CABLES

The most important test carried out during the verification of an electrical installation is related to the quality of insulation. As noted earlier, insulation deteriorates with age. In addition, some insulation will have been subjected to mechanical wear and tear, cables may have been subjected to overloads causing excessive heat, et cetera.

What happens when the insulation deteriorates? The current flowing through the insulation will increase and can reach dangerous values, causing electrical shocks and fire.

The quality and the condition of the cables is verified by measuring the *insulation resistance*.

HOW TO MEASURE THE INSULATION RESISTANCE

Principle: apply a stable continuous voltage for a defined period, measure the resulting current between the two parts under test, and ascertain with Ohm's Law that the insulation resistance is higher than the minimum value required by the standards.

Measurements should be carried out with an insulation tester. An insulation tester used during the initial verification will eliminate short-circuits or short to earth faults. During periodic verifications, the insulation tester will also help test the integrity of the cables by revealing insulation failures that could result in shock and fire.

The test is made between the active conductors (phase and neutral) and the PE (protective conductor) connected to the earthing arrangement. For the purpose of this test, active conductors may be connected together. The dc voltage applied between the live conductors (de-energized) and the earthing arrangement, will cause a very small current to flow through the conductor and the insulation. The higher the current, the lower the resistance (R=E/I). The current will increase as insulation deteriorates.

A low insulation resistance means that a leakage current is flowing through the insulation to earth. This leakage current could shock an individual if there is no RCD or if there is an accidental interruption of the Protective Earth conductor. A leakage current of 500 mA can generate enough heat to ignite the surrounding materials, involving the risk of causing a fire.

According to the IEC 60364-6, the following table applies:

Table — Minimal values of insulation resistance

Nominal circuit voltage **V**	**Test voltage dc** **V**	**Insulation resistance** **MΩ**
SELV and PELV	250	$\geq$ 0.5
Up to and including 500 V, including FELV	500	$\geq$ 1.0
Above 500 V	1,000	$\geq$ 1.0

The insulation resistance, measured with the test voltage indicated in the table, is satisfactory if each circuit (with the appliances disconnected) has an insulation resistance not less than the appropriate value given in the table. However, where a reading of less than 2 MΩ is recorded for an individual circuit, there is the possibility of defective insulation and it may be necessary to replace the cable.

COSTS INVOLVED

The cost of an insulation tester is not excessive and the extra time needed to measure the insulation resistance when carrying out verification is small compared to the profit of having a good visualization of the quality of the electrical installation. Bad contacts can be remedied and bad cables replaced before a fire breaks out.

CONCLUSIONS AND RECOMMENDATIONS

One cannot state unequivocally that all old wiring in the homes is a hazard. The main concern is to determine the condition of the cables and their insulation. Insulation becomes damaged when it is pierced or undergoes other mechanical damage as well as when a circuit is overloaded. The cable becomes hot and the insulation will crack after a time.

It is clear that a verification of an existing electrical installation without testing does not providing a sufficient indication of the state of the most important safety issue of an existing installation, i.e. the insulation quality of the cables. It will only reveal visible damage to the electrical equipment due to wear and tear and mechanical damage. When no tests and measurements are carried out, it could give a false sense of safety.

Therefore, verification should always be comprised of an inspection *and* tests.

Many home fires can be avoided if the electrical installation is tested with an insulation tester and if cables that are not up to standard are replaced.

To avoid the problem of bad contacts, it is good practice to replace the entire cable when a section of a cable is damaged.

It is good practice to remove obsolete cables to reduce potential fuel load. There is better fire performance using the new vinyl compounds compared to the traditional compounds

Due to the specific hazards related to the use of aluminium wiring (especially in homes in Eastern Europe), it is good practice to replace them with copper wiring at the first sign of degradation or bad contacts.

BIBLIOGRAPHY

IEC 60364-6: Low-voltage installations / Part 6: Verification

'Towards improved electrical installations in European homes' — European Copper Institute

'Overview of electrical safety in 11 countries' — European Copper Institute

US Fire Administration Publications

ESFI (Electrical Safety Foundation International) Publications

'Reducing the fire hazard in aluminium-wired homes' – J. Aronstein, Ph.D.