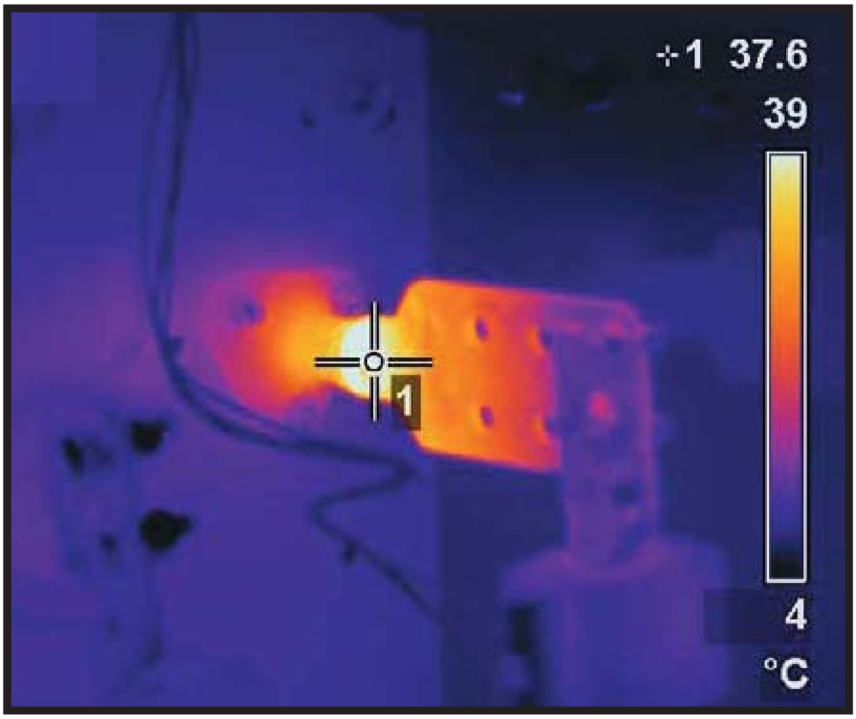


PERIODIC INSPECTION OF CRITICAL SYSTEMS

By Mark Coles

WHEN UNDERTAKING periodic inspections, contractors are often refused permission to shut down parts of an installation to carry out the required tests; the contractor duly records a limitation on the Periodic Inspection Report. The situation can go on for years and elements of an electrical installation are never assessed, which of course, does not comply with BS 7671 or the Electricity at Work Regulations 1989; electrical installations must be tested and inspected at regular intervals.

The Standards and Compliance department here at the IET is often asked if there any additional inspection methods that can be employed to ensure the continuing reliability of critical systems.

THE NEED FOR PERIODIC INSPECTIONS

Over time, electrical installations degrade due to a number of factors; loading, overheating, environment, mechanical damage, wear and tear, poor maintenance, etc. It is therefore important that any deficiencies in the installation are found and corrected as soon as possible.

The law

The law requires that electrical installations are maintained and kept in a safe condition. The following extract from the Electricity at Work Regulations 1989, Regulation 4, places a duty on employers to provide safe systems for their workers:

Regulation 4 of the Electricity at Work Regulations 1989

Systems, work activities and protective equipment

*(1) All **systems** shall at all times be of such construction as to prevent, so far as is reasonably practicable, **danger**.*

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

*(4) Any equipment provided under these Regulations for the purpose of protecting persons at work on or near **electrical equipment** shall be suitable for the use for which it is provided, be maintained in a condition suitable for that use, and be properly used.*

Competency

The law requires that the operation, maintenance and testing of electrical systems and equipment should be carried out only by those persons who are competent for the particular class of work. The use of people who are properly trained and competent to work on live equipment safely is a legal requirement.

The following extract from the Electricity at Work Regulations 1989, Regulation 16, defines competency:

Regulation 16 of the Electricity at Work Regulations 1989

Persons to be competent to prevent danger and injury

*No person shall be engaged in any work activity where technical knowledge or experience is necessary to prevent **danger** or, where appropriate, injury, unless he possesses such knowledge or experience, or is under such degree of supervision as may be appropriate* *having regard to the nature of the work.*

The requirements of BS 7671

One of the essential requirements of BS 7671 is stated in Regulation 130-01-01. This Regulation sets the scene for Chapter 13, Fundamental Principles. The requirements of Chapter 13 are intended to provide for the safety of persons, livestock and property against dangers and damage which may arise in the reasonable use of electrical installations. Risk of injury may result from shock currents, excessive temperatures likely to cause burns, fires, other injurious effects and explosion.

It is therefore a requirement to select the correct equipment and install in a suitable manner for the particular application. It is also a requirement that such installations be periodically inspected and tested to ensure ongoing safety.

Chapter 73 of BS 7671, Periodic Inspection and Testing, states that, where required, periodic inspection and testing of every electrical installation shall be carried out to determine whether the installation is in a satisfactory condition for continued service.

The frequency of periodic inspection and testing should be determined by taking into account the type of installation, the use and operation, the frequency and quality of maintenance and the external influences to which it is subjected.

Table 3.2 of The IEE publication Guidance Note 3 – Inspection and Testing provides guidance on the frequency of formal inspections of electrical installations as well as the routine checks.

The formal inspections should be carried out in accordance with Chapter 73 of BS 7671. This requires an inspection comprising careful scrutiny of the installation, carried out without dismantling or with partial dismantling as required, together with the appropriate tests of Chapter 71.

THE PERIODIC INSPECTION

In smaller installations, such as those in domestic properties, the periodic inspection is a relatively straight-forward process. The installation would be under the control of the inspector and they may shut down parts or all of the installation at will to undertake the relevant tests. On larger installations, this is not so easy.

Consider an electrical installation in a hospital or a bank. The duty holder has refused the contractor permission to shut down parts of the installation for patient welfare, safety or for security reasons. The contractor would then make reference to this situation on the Periodic Inspection Report (see figs 1 & 2 below). Installations that have such critical loads, like hospitals and banks, cannot afford supply failure. Failure of a piece of distribution equipment or a distribution cable, for example, which causes an interruption of supply, could be extremely dangerous as well as financially disastrous for the organisation.

The irony is that those circuits for which permission to isolate is refused are those which require the most scrutiny to ensure that they do not fail...

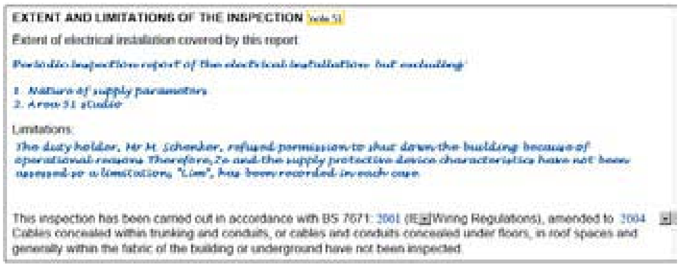
The contractor cannot insist on shut down to assess the installation but the duty holder still has a duty of care to ensure that their systems are safe. To comply with BS 7671 and the Electricity at Work Regulations 1989, the Duty holder must make available all parts of the installation for periodic inspection.

Problems and hidden dangers

Visual inspections of electrical installations will pick up most common problems, e.g. if the method of installation is unsuitable for the environment in which it is located, mechanical damage due to impact or abrasion will generally be obvious and any problems associated with wear and tear, such as loose screws or covers, will be clearly apparent.

If elements of the installation are not inspected, problems may therefore go undetected.

Loose terminals, located within an enclosure, can cause overheating in conductors and equipment. The heating effect is due to an increase in


EXTENT AND LIMITATIONS OF THE INSPECTION

Extent of electrical installation covered by this report

Periodic inspection report of the electrical installation but excluding:

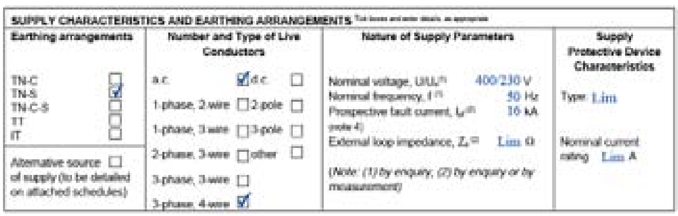
1. Nature of supply parameters
2. Area 51 studio

Limitations:

The duty holder, Mr M. Schenker, refused permission to shut down the building because of operational reasons. Therefore, Ze and the supply protective device characteristics have not been assessed as a limitation, "Lim", has been recorded in each case

This inspection has been carried out in accordance with BS 7671: 2001 (IEE Wiring Regulations), amended to 2004
Cables concealed within trunking and conduits, or cables and conduits concealed under floors, in roof spaces and generally within the fabric of the building or underground have not been inspected

Fig 1: **Extent and limitations of the inspection – extract from page 1 of the model form Periodic Inspection Report for an Electrical Installation**


SUPPLY CHARACTERISTICS AND EARTHING ARRANGEMENTS

Earthing arrangements	Number and Type of Live Conductors	Nature of Supply Parameters	Supply Protective Device Characteristics
TN-C ☐ TN-S ☑ TN-C-S ☐ TT ☐ IT ☐	a.c. ☑ d.c. ☐ 1-phase, 2-wire ☐ 2-pole ☐ 1-phase, 3-wire ☐ 3-pole ☐ 2-phase, 3-wire ☐ other ☐ 3-phase, 3-wire ☐ 3-phase, 4-wire ☑	Nominal voltage, U/U₀ (1) 400/230 V Nominal frequency, f (1) 50 Hz Prospective fault current, Ipf (2) 16 kA (note 4) External loop impedance, Ze (2) Lim Ω (Note: (1) by enquiry, (2) by enquiry or by measurement)	Type: Lim Nominal current rating Lim A
Alternative source of supply (to be detailed on attached schedules) ☐			

Fig 2: **Supply characteristics and earthing arrangements – extract from page 2 of the model form Periodic Inspection Report for an Electrical Installation**

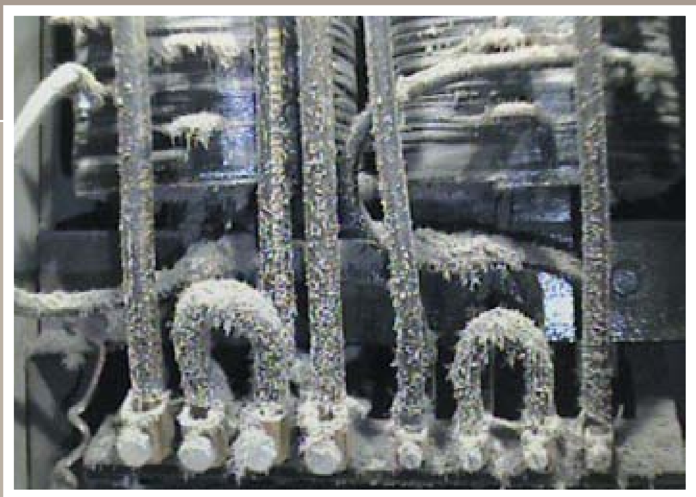


Fig 3: Accumulation of dust on terminations

Fig 4: Accumulation of dust in equipment

resistance across the joint; as heat rises, the insulation can fail which could cause an arc or even an explosion in some cases.

Arcing is an electrical discharge that begins at full intensity and can end just as abruptly. A path to earth develops as the insulation breaks down and high temperatures are reached very quickly.

A build-up of dust and debris, undetected over time, can cause arcs, tracking, short circuits and faults within equipment. Clearly, this is a major fire hazard.

Tracking is a problem that will build in intensity; like arcing, it will develop a path to Earth and accelerate the deterioration of insulation. Tracking is visually evident by carbon residue or 'tracks'.

There are other problems found in electrical installations, which a general periodic inspection would not necessarily discover. Mechanical vibration, for example, is a problem that can only be detected when the equipment is energised and running. Generally, the source of the vibration can be related to a number of issues including contactor or relay chatter, transformer delaminating, loose fixings or worn parts on equipment.

Overloaded circuits can also cause overheating in conductors and equipment.

Harmonics

Harmonics are generated when a load draws a non-linear current from a sinusoidal supply. Switch-mode power supplies, used extensively in computer and IT equipment, or variable frequency drives (VFDs), used to control electric motors, for example, can distort the voltage and current waveforms; high 3rd order harmonic current is typical for switch-mode power supplies. 3rd, in addition to other triple, harmonics combine in the neutral conductor and create a neutral current that has a magnitude equal to the sum of the third harmonic content of each phase. The heating effect of this increased neutral current can have an influence on the temperature at which a cable operates, particularly where multicore cables are used. The tables of current-carrying capacity, as shown in Appendix 4 of BS 7671, assume that at full load the neutral current will be zero and will therefore not contribute to the heating effect of the cable. In reality, the resultant neutral conductor current can be well above the current-carrying capacity for the cable.

This can be extremely dangerous as neutral conductors, which are not fuse or MCB protected, can overheat.

OTHER METHODS OF ASSESSMENT

New technologies, such as Infrared Thermography and Ultrasonic Testing, are methods which allow for the assessment of energised electrical installations. The technology provides for early detection of problems and potential catastrophic failure of the equipment and associated components but should not be used as a replacement for regular programmed periodic inspections.

Infrared Thermography

Infrared Thermography is based on the principle that all materials emit electromagnetic radiation which can be detected by an infrared camera.

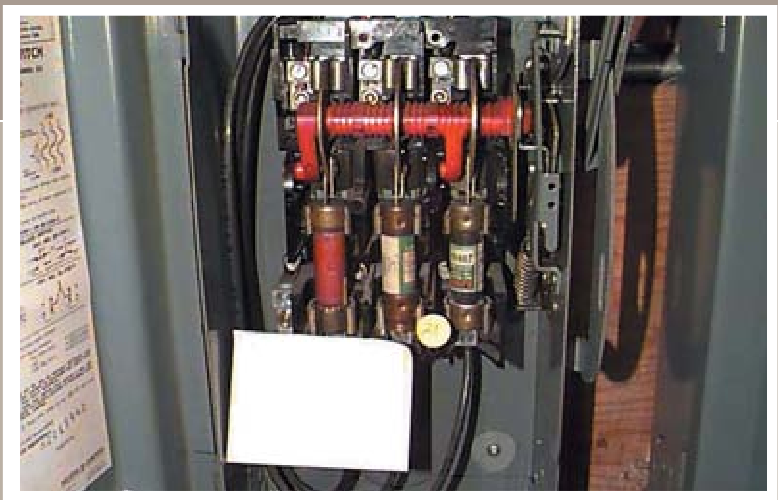


Fig 5: Positive image of an item of switchgear

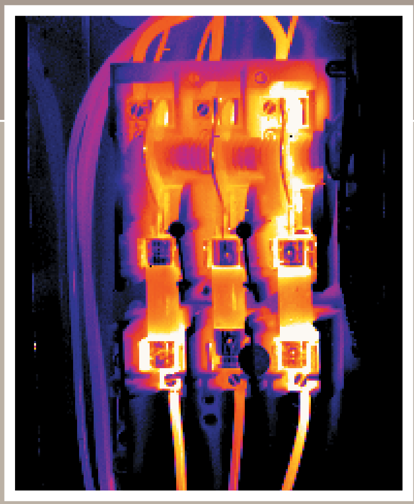


Fig 6: Infrared image

The amount of radiated energy detected is translated into temperature information based on the laws of quantum physics. All materials above the hypothetical temperature of absolute zero, (-273.15ºC, 0 kelvin) will emit this energy.

In electrical installations, heating effects are created and generated as a result of numerous factors including cyclical-load operations, insufficient cross-sectional area of conductors, types of loads and system deterioration.

A common point of failure, related to heating in electrical applications, is at the terminations of conductors. In many cases this is due to an increase in the resistance of that joint or connection which is directly related to the thermal energy that can be identified.

The following images show how infrared technology can be used as an inspection and diagnostic tool.

Figs 1 and 2 show an item of switchgear; fig 1 is the positive image of the equipment, fig 2 is the infrared image. Note that darker areas of the infrared image are cooler; whiter areas are warmer. It can therefore be seen from fig 2 that parts of the equipment are hotter than others; these areas are terminations and/or contacts and the increase in temperature will be due to an increased resistance across the joint.

Fig 7 shows the positive image of an MCB in a distribution board; fig 8 shows the infrared image.

As can be seen from fig 8, one circuit is operating at a far higher temperature than others within the same distribution board.

Note that raised temperatures on one or even a number of circuits may not be a cause for concern; some circuits are designed to operate up to 70ºC, others may even be designed to operate up to 90ºC. Problems occur where a particular element of a circuit is far hotter than the remainder and these ‘hotspots’ can deteriorate very rapidly.

An increase in resistance not only creates heat at connections and joints, which is the simple Ohm’s Law relationship but also fatigues the apparatus reducing useful service life and increases the risk of fire. The increased resistance will cause an increase in power loss at the termination, which in turn increases energy costs; again the increase in emission of thermal radiation will be detected by the infrared camera.

Ultrasonic Testing

The National Aeronautics and Space Administration (NASA) in the USA developed ultrasonic technology in the 1970s as a tool for analysis procedures on the Space Shuttle programme. Ultrasonic frequencies are those that are found between the ranges of 20kHz to 100kHz; the average range for human hearing is between 20Hz and 16kHz. Some emissions related to electrical issues can be in the ultrasonic frequency range and will therefore be beyond our hearing capabilities. The ultrasound technology detects the ionisation of air as it produces turbulence in electrical applications, particularly in systems below 1000 volts.

The main concerns are arcing, tracking, contactor or relay chatter and mechanical vibration.

Fig 7: Positive image of an MCB in a distribution board

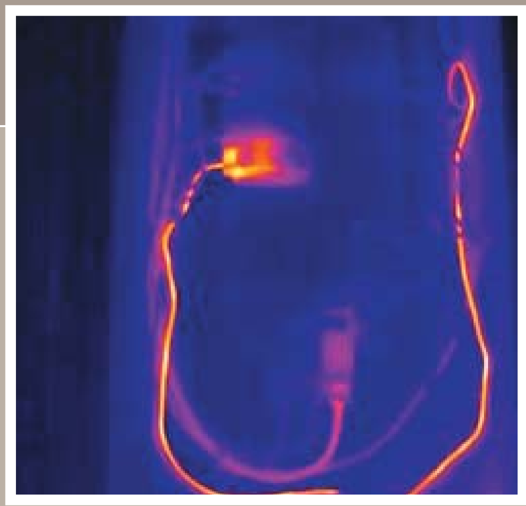


Fig 8: Infrared image

The advantage of using this technology is that it may be employed where sight and access are restricted. Ultrasonic emissions generated in electrical equipment can escape through any opening in the enclosure, such as a door seal, cooling vent or seams around integral components; the emissions are detected by probe.

Additionally, problems associated with sealed or liquid-filled equipment can be identified by employing a contact probe. In this configuration, the probe becomes a wave-guide for sound and channels any emission that exists internally within the equipment into the probe. The unit will process the signal and demodulate it into a sound audible to human hearing. Once electronically recorded, the frequency content can be analysed using application software.

All electrical anomalies can be identified as they have a unique spectral 'signature'. By comparing recordings with known samples, software can isolate the type of anomaly, identify the source and gauge its severity relatively accurately. These can be either in the FFT (Fast Fourier Transform) frequency analysis, the time series domain, or both for proper interpretation.

PRESENTING THE FINDINGS

Early discussions will establish exactly what the client requires from the inspection. The client should be made aware that the use of infrared and ultrasonic technology to assess an electrical installation is not a replacement for an on-going periodic inspection and testing regime and it does not provide the information as required in the model Periodic Inspection Report form, as Appendix 6 of BS 7671.

However, contractors may use the model Periodic Inspection Report form, where pertinent, augmented by the findings from infrared and ultrasonic inspections. Software packages will enable the results to be interpreted and presented in an efficient manner.

Such methods are over and above the requirements of BS 7671 but, nevertheless, the technology will be a valuable maintenance and diagnostic tool to some organisations.

FURTHER INFORMATION

The model form Periodic Inspection Report for an Electrical Installation, in addition to model forms of the Electrical Installation Certificate and the Minor Electrical Installation Works Certificate may be downloaded free of charge from the IET's website, at www.theiet.org/technical and select the option Forms for electrical contractors.

Thanks to TEGG for the images used