Guidelines for Low Voltage (LV) Electrical Installations of Buildings: Verification by Inspection and Testing For Submitting Person (SP) and Electrical Contractor (EC)

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Contents

Disclaimer

These guidelines provide recommended minimum requirements for verification by inspection and testing on the compliance of low voltage electrical installations of buildings by submitting person and electrical contractor with statutory and regulatory requirements, and the requirements of IEC 60364 and BS 7671.

All requirements contained in this guideline are recommendations only and are not warranted to be suitable for any particular installations, error–free, and do not constitute legal advice or opinions of any kind. Users of any requirement of this guideline shall be responsible in making assessments and judgment of its safe to use, suitability, reliability, direct, indirect, consequential and latent risks, and any legal implication arising of use in each particular installations and situation. The developer of this guideline disclaims any liability, responsibility, losses, damages, causes of action of any nature, either directly or indirectly or implied arising out of or in connection with the use of any requirement of this guideline.

1. Scope

These guidelines document recommended minimum requirements for the verification by inspection and testing (I & T), for the compliance of low voltage (LV) (Note: 1) electrical installations of buildings, (installations (Note: 2)) with statutory and/or regulatory requirements (Note: 3), and requirements as specified in IEC 60364 Part 6 and BS 7671 Part 6 (Note: 4).

The plans and procedures, which shall include main and all supplementary plans and procedures, (PP) described in this guideline cover I & T activities for off–site and/or on–site installations, installations during construction, newly completed installations and existing installations after alteration.

This guideline is developed to facilitate the work of the Submitting Person (SP) (Note: 4), who is the installation authorised LV electrical system competent representative, such as professional electrical engineer, in the following aspects, with reference and/or compliance with this guideline:-

1) To guide the Electrical Contractor (EC) (Note: 4) in preparing the proposed PP;

2) To vet and approve the proposed PP submitted by the EC;

3) To ensure that the EC carries out and completes all electrical erection works, settings, such as coordination setting of over–current protective devices, performance measurements of measuring equipment and all other works necessary to be completed prior to I & T works

4) To ensure that the I & T works are carried out correctly;

5) To witness the I & T works; and

6) To review, accept and endorse the I & T documents such as reports, certificates, other supporting data and documents.

Depending on specific requirements of individual installations, the EC shall submit supplementary PP when and/or as appropriate for non–conformance and deviations such as additional and/or modified requirements, additional and/or special tests requested by the SP, with regards to any element of the installation other than those described in the main PP.

The EC shall carry out I & T works in compliance with the approved PP.

Note: 1 – LV refers to low voltage electrical supply system with nominal voltages complying with IEC 60038: IEC Standard Voltages

Note: 2 – Installations shall include the following: -

1) LV electrical installations of buildings complying with IEC 60364: Electrical Installations of Buildings and/or BS 7671: Requirements of Electrical Installations, including their associated and/or replaced standards such as IEE Wiring Regulations, and national deviations

2) LV switchgear and controlgear complying with IEC 60439: Switchgears and Controlgears and/or IEC 61439: Switchgears and Controlgears (Note: IEC 60439 was withdrawn and replaced by IEC 60439 in the year 2009)

3) Any LV electrical apparatus, equipment, system or combination thereof, that is part of the electrical works such as electric motors, standby generators, uninterruptable power supplies, and isolated power supply systems.

4) Temporary works to facilitate I & T works.

5) All others engineering work or installation specific engineering work specified and/or requested by the SP.

Note: 3 – Refers to national laws, Acts, statues and regulations, and deviations

Note: 4 – SP and/or EC shall include her/his authorised representatives

2. Objectives

The objectives of these guidelines are:-

1) To verify that the installation meets and/or exceeds statutory and/or regulatory requirements, design intents, requirements of IEC 60364 and/or BS 7671 and specific requirements of individual installations as specified in the construction document prior to release to the user.

2) To verify that the installation is erected, inspected and tested, and with non–conformance remedied, in accordance with design intent prior to release to the user;

3) To verify safe, proper, and reliable functioning and performance of the installations prior to release to the user;

4) To carry out the verification process safely, efficiently and effectively;

5) To record systematically and efficiently I & T safety, performance, functioning and other necessary data as baselines for safe, efficient and effective operation and maintenance, and disposal of the installation after release to the user.

3. General

3.1 Submitting Person (SP) and Electrical Contractor (EC)

The SP and EC shall be trained, competent, qualified and certified in compliance with regulatory and/or statutory requirements

The SP and EC shall have full technical knowledge and sufficient understanding of the installations as documented in the approved construction document (Construction document) and requirements of this guideline.

3.2 Submission, Approval and Execution of I & T works

The EC shall prepare and submit the PP, and carry out all I & T works of the approved PP.

The SP shall vet, approve and endorse the PP and witness, review, approve and endorse the I & T works carried out in accordance with the approved PP.

3.3 Preparation of Proposed Plans and Procedures (PP)

The EC should take the following steps to prepare the proposed PP:-

1) Discuss with the SP on the contents and requirements, and extent of I & T works to be included in the PP;

2) Discuss the format of PP and the I & T document such as job safety analysis (JSA), method statements, and records;

3) Obtain all construction documents such as approved design, shop and as built drawings and specifications, method statements, equipment schedule and technical specifications and erection manuals, and operations and maintenance manuals;

4) Review, understand and be thoroughly acquainted with the intents and requirements of the construction documents;

5) Assess any characteristics of installations likely to have harmful effects, degradation and/or damage by other equipment or other services, or the electricity supply. Those characteristics include the following:-

    a) Overvoltages;

    b) Undervoltages;

    c) Fluctuating loads;

    d) Unbalanced loads;

    e) Power factor;

f) Starting currents;

g) Power quality such as harmonic currents, voltage sag, transients;

h) Direct current (d.c.) feedback;

i) Necessity for additional connection to earth;

j) Special installation, protective measures, etc.,

6) Check compliance of the construction document with statutory and/or regulatory requirements;

7) Check the requirements of design intents and IEC 60364 and/or BS 7671, and record all deviations from IEC 60364 and/or BS 7671 with explanation for deviations;

8) Inspect the installation to ensure compliance with construction documents;

9) Identify non–conformances from the construction documents and carry out all necessary remedial actions;

10) Check that individual components, such as light fittings, switches, socket outlets, protective devices, are properly labelled, set and/or adjusted, and functionally tested;

11) Ensure that manufacturer/supplier's documentation such as manufacturer's management system certification to ISO 9000, etc., equipment/product/material test and certification, factory test and quality control data/report, equipment/product/material acceptance test reports, etc., are complete, properly reviewed, approved and endorsed by the SP, and collated as part of the as–built documents;

12) Ensure that all personnel who are involved in I & T works are trained, qualified and certified, and comply with all statutory and regulatory requirements. The PP shall include evident such as training, qualifying and certification records;

13) Ensure that all personnel (Competent Person (CP)) who carry out I & T works understand and are thoroughly acquainted with all requirements of the PP and all safety requirements necessary to carry out I & T works, especially installation specific safety requirements. Safety requirements documentation is mandatory in PP in the form of Job Safety Analysis (JSA) or equivalent. The PP shall include evidence of competency and safety training.

14) Discuss the types, sequence and/or order of elements of I & T works with SP to optimise I & T works. Each PP is unique to specific installations, and shall include only those elements that are essential to verify safety to use, reliability, functioning, performances, and effective and efficient operation and maintenance of the installations;

15) Prepare the PP and submit to the SP for approval and endorsement.

3.4 Standards, Specifications, Technical Manuals, etc., and Equivalent

All standards, specifications, technical manuals, etc., described in these guidelines shall imply their equivalent, subjected to the approval of the SP

3.5 Personnel Involved in or Witness and/or Carry out I & T works

The SP shall be trained, qualified and certified in compliance with statutory and/or regulatory requirements and shall comply with the requirements of safety, especially against generic installation hazards such as civil, chemical, electrical and mechanical hazards and specific installation hazards

Except for installation equipment such as switches and socket outlets which are designed for un–informed users, specified by statues and/or regulations or specified explicitly in the PP, only CP are permitted to operate and/or carry out any I & T works. The CP who carries out I & T works shall be trained, qualified and certified in compliance with statutory and/or regulatory requirements and shall comply with the requirements of safety against generic and specific installation hazards.

Only CP who are trained and certified, have a valid testing license issued by the relevant regulatory body if required, and who can demonstrate the ability to operate test instruments safely and reliably shall be permitted to operate test instruments. The CP shall operate test instruments in accordance with the manufacturer's safety, and operation and maintenance instruction and carry out the test per PP or as instructed by the SP.

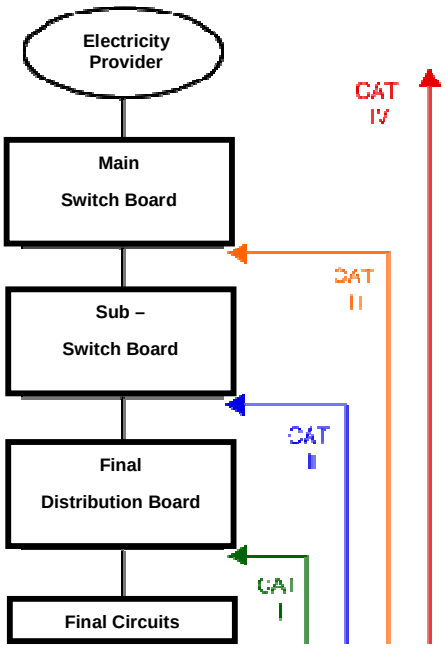
All personnel, such as the installation project manager and facility manager, who are involved and/or witness but not carrying out I & T works shall comply with the requirements of generic and specific installation hazards.

All personnel who are involved in, witness and/or carry out I & T works shall be briefed, understand and be thoroughly acquainted with the requirements of the I & T works to be carried out.

All personnel, who shall assume all professional responsibility for relevant I & T works in this guideline, such as the SP and EC shall include their authorised deputies, representatives, etc., and shall have training, qualification and certification acceptable as equivalent to those processed by the person.

3.6 Testing and Measuring Equipment (Test Instrument)

All test instruments shall comply with IEC 61010: Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use, and especially shall be of measurement category in compliance with IEC 61010-20-030: Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory use – Part 30 Special Requirements for Testing and Measuring Circuits. Figure 3.5 shows the measurement categories and Table 3.5 shows the withstand voltages.



Schematic representation of measurement categories

Table 3.5: Measurement Categories to IEC 61010				
Nominal Voltage	**CAT IV**	**CAT III**	**CAT II**	**CAT I**
150V	4,000 V	2,500 V	1,500 V	800 V
300 V	6,000 V	4,000 V	2,500 V	1,500 V
600 V	8,000 V	6,000 V	4,000 V	2,500 V
1,000 V	12,000 V	8,000 V	6,000 V	4,000 V
Resistance	2 Ω	2 Ω	12 Ω	30 Ω

The EC shall use test instruments for I & T works and is encouraged to use test instruments for any preliminary measurement but non–I & T works.

The EC shall propose, supply and operate all test instruments suitable for I &C works or as stipulated in the construction documents. This test instrument shall be calibrated and/or verified by or tested by accredited laboratories or equivalent in compliance with ISO/IEC 17025: General Requirements for the Competence of Testing and Calibration Laboratories or equivalent.

The EC shall ensure all I & T measurements are measured with test instruments and the measured values shall be corrected for correction factors.

3.7 Preferred Sequence of I & T Works

In general, inspection shall precede testing.

The sequence of I & T works in these guidelines is the preferred sequence. The EC with the approval from the SP can modify the sequence of I & T works.

3.8 Elements of I & T Works

The elements of I & T works in these guidelines are the recommended schedule. Any element can be modified and/or omitted upon approval by the SP.

Additional elements of I & T works can be added in the PP if requested by the EC or SP

The elements of I & T works can be assigned to different EC subject to approval by the SP.

3.9 Electrically Dead Installations

It is recommended that I & T works be carried out with the installation electrically dead.

The CP shall test to ensure that the installation is electrically dead and shall carry out tag–in and tag–out procedures to prevent accidental energisation of electrical supply.

3.10 Off–Site and On–Site I & T Works

I & T works can be carried out off–site fully and/or partially, such as factory acceptance test at manufacturer's premise or third–party test laboratory, during construction, after completion of construction, in stages of construction or in any combination there-off.

3.11 Temporary Works and/or Modification during I & T Works

The EC may have to carry out temporary works and/or modifications, as I & T works progress. Any temporary works and/or modifications shall be reinstalled to its original as–constructed after completing the I & T. Reinstallation I & T verification works shall be approved and endorsed by the SP.

All temporary works and/or modification works and its re–installation I & T verification works shall be submitted in supplementary PP and shall only proceed after approval by the SP.

3.12 Remedial Actions

Any non–conformance, such as deviation, defects, equipment failure, etc., shall be documented in the I & T report as a non–Conformance Report (NCR) with a description of the non–conformance, detailed root cause analysis, proposed remedial action to be taken to remedy the non–conformance and remedy confirmation I &T verification work.

Remedial work shall be carried out only after acceptance of the root cause analysis and approval of remedial action by the SP.

The non–conformance shall be deemed remedied only after the NCR is closed and endorsed by the SP.

In the event of any I & T work results in non–conformance such as measurement and non–conformance erection method, and if the results of those preceding I & T work(s), may have been influenced by the particular non–conformance, the I & T and those affected preceding I & T work(s) shall be repeated after the non–conformance has been remedied. The EC shall submit the remedial and re–I & T works in supplementary PP to the SP for review, approval and endorsement. The EC shall carry out remedial and retest I & T works only after approval of the PP.

3.13 Documentation and Deliverables

All I & T activities shall be documented in writing such as NCR, I & T results, measurement and/or setting reports, reports on deviations, non–conformance, site adjustment and/or conditions (Report)

The report shall record I & T activities with sufficient details, endorsed by the CP who carried out the I & T works, reviewed, approved and endorsed by the SP and witnessed at least by an independent party such as the client's representative.

It is recommended that the EC submit individual I & T work completed to the SP for review, approval and endorsement as soon as possible after completion of the relevant I & T work.

Where required in the construction document, the EC shall carry out a final evaluation of the safety, reliability, functioning and performance of the installation, the results of which shall be recorded in the commissioning report which shall be reviewed, approved and endorsed by the SP.

Upon completion of all I & T works, the EC shall compile and submit all I & T reports and/or all documents, such as the document submitted to statutory bodies, as part of the as–built documents within 2 working weeks of completion of the I & T works or within a duration mutually agreed by the EC and SP.

3.14 I & T Approval Team

The SP shall review and shall have final professional discretion in approving and endorsing all I & T works and activities.

Besides the SP, It is recommended that all I & T works in these guidelines should be reviewed, approved and endorsed by others who provide independent support for the installation such as the safety officer, or installation quality control and assurance personnel.

3.15 Submission to Regulatory Bodies

The EC shall submit all necessary properly endorsed documents and arrange all processing fees, contributions, etc., payable in compliance with statutory and/or regulatory requirements to regulatory bodies.

3.16 Preparation of As–Built Documents

The EC shall collate and prepare all I & T documents as part of the as–built documents. The number of copies and the format shall be per contract or as approved by the SP

3.17 Safe – Keeping of the I & T documentation by EC

The I & T documentation shall be kept by the EC for a minimum period of ten (10) years after the issuance of the certificate of completion of the installation or as specified in the contract or by the SP, whichever is longer.

4. Inspection Procedures

Inspection should be carried out to confirm that the installation:-

1) Is in compliance with statutory and regulatory requirements, design intents, IEC 60364 and/or BS 7671, installation standards, etc.,

2) Is designed, supervised and verified by qualified personnel, especially the requirements for qualified installers, and Competent Person as verified by inspection and test;

3) Components are selected, delivered, stored, fabricated and erected correctly in accordance with design intent, installation standard and/or industrial best practices, approved construction document and manufacturer's recommendation;

4) Do not have visible non–conformance beyond acceptable criteria, especially so as not to impair safety, reliability, functioning and performance of the installation;

5) Has adequate protection against external factors, unauthorised access, degradation of safety, reliability, functioning and performance of equipment;

4.1 Mandatory Inspection

Mandatory Inspection shall include the following:-

1) Inspect compliance with statutory and regulatory requirements, standards, design intents, safety requirements, method statements, construction document, PP. etc.;

2) Inspect quality, quantity, handling, storage, protection against external influences, etc., of materials;

3) Inspect qualification and certification of installers, Competent Person, supervisors, etc.,

4) Inspect compliance with erection methodologies, especially safety for use, function and perform as design intent, optimise interference with other trades, etc.,

5) Inspect visual non–conformance such as visual damages, inadequate protection against external influences, protection against damages – temporary or permanent, theft, etc.,

6) Inspect the layout and erection of equipment, especially access for safe operation and maintenance by end user and protection against unintentional access and hazards by un–informed users.

7) Inspect that the site is properly house–kept, properly secured against unauthorised access, and periodically maintained during the erection period if necessary.

8) Inspect correct and adequate labeling, especially danger signages;

9) Inspect correct and proper use of test instruments and that Competent persons are qualified and certified.

10) Inspect for proper, effective and efficient documentation and for proper review, approval and endorsement procedures.

4.2 Inspection Prior to Erection

Inspection prior to erection may include the following:-

1) Inspect manufacturer/supplier's quality management system such as ISO 9000;

2) Inspect adequacy of documentation such as factory acceptance report (FAT), certifications;

3) Inspect apparatus, equipment, material (construction materials) and constructional methodologies compliance with best practices, standards and construction document;

4) Inspect construction materials quality, certification, test reports, etc.,;

5) Inspect construction material delivery, storage methodologies and protection against external influences;

6) Inspect installation for protection against safety requirements, protection against external influences and in accordance with coordination plan with other trades;

7) Inspect correct construction specifications and methodologies such as exclusion of wet services in electrical plant room and riser compartment.

4.3 Inspection during Erection

Inspection during erection may include the following:-

1) Inspect correct and adequate documentation such as job safety analysis, method statement, certified installers;

2) Inspect correct construction material used;

3) Inspect correct erection methods;

4) Inspect correct coordination with other trades;

5) Inspect correct earthing system installation;

6) Inspect correct lightning protection installation;

7) Inspect continuity of circuit conductors, especially protective and equipotential bonding conductors.

4.4 Inspection after Erection

Inspection after erection may include the following:-

1) Inspect correct erection of installation;

2) Inspect adequacy of access for convenience of identification, operation and maintenance;

3) Inspect correct and reliable terminations and connections, and jointing of conductors;

4) Inspect adequacy of identification and labeling of circuits, fuses, switches, terminals, etc;

5) Inspect correct sizes of conductor and cable management systems;

6) Inspect correct connections of all equipment with special attention to socket outlets, lampholders, isolators, switches, residual current devices, miniature circuit breakers, and protective and equipotential bonding conductors;

7) Inspect correct erection of fire barriers and protection against thermal effects;

8) Inspect correct erection of basic protection with live parts, including measurement of distances where appropriate, that is, protection by insulation of live parts, or protection by barriers or enclosures;

9) Inspect adequacy and appropriate circuit devices for isolation and switching;

10) Inspect correct selection, sizing, erection and setting and coordination of protective devices;

11) Inspect correct selection, sizing, erection and verification of indicating and measuring instruments such as ammeter, voltmeter, power meter;

12) Inspect adequacy and correct labeling of circuits, fuses, protective devices, switches, isolators. terminals, equipment/systems, especially multi–source equipment/systems;

13) Inspect correct and optimised selection of equipment and protective measures appropriate to adverse environmental conditions;

14) Inspect adequacy and correct presence of danger and warning notices;

15) Inspect and ensure presence and sufficiency of schematic diagrams, instructions and other similar information;

16) Inspect correct connection of single pole devices for protection or switching in phase conductors only;

17) Inspect correct method and erection of protection against indirect contact;

18) Inspect adequacy of protection against access by unauthorised or un–informed personnel or user;

19) Inspect adequacy of prevention of mutual and external influence;

20) Inspect presence and sufficiency of under-voltage and over-voltage protective devices;

21) Inspect correct interface with other trades such as terminations into air–conditioner and fire protection systems;

22) Inspect that any other I & T works specified in PP or requested by the SP are carry out correctly;

23) Inspect protective earthing system and equipotential bonding system;

24) Inspect for correct type of insulating mat;

25) Inspect all post–erection works such as housekeeping, physical protection and tag–in and tag–out, are completed prior to commissioning works; and

26) Inspect that the installation is properly cleared of non–installation materials, and equipment, properly secured and in ready for hand – over.

4.5 Inspection for Hazardous Explosive Atmospheres Location(s)

Inspection for hazardous explosive atmospheres location(s) may include the following:-

1) Inspect correct design and erection methodologies in compliance with IEC 60079: Explosive Atmospheres, in addition to design intent and IEC 60364 / BS 7671;

2) Inspect correct selection and quality control of construction material;

3) Inspect apparatus/equipment such as lamps, fuses, cable and cable management are of correct type and rating in compliance with IEC 60079;

4) Inspect correct erection of installation;

5) Inspect correct installation of hazardous gas detection system;

6) Inspect that fire protection systems are installed;

7) Inspect where appropriate, the area involved is ‘hazardous gas free’ condition before insulation and earth fault loop impedance test are carried out;

8) Inspect that integrity of the type of protection provided for the equipment is not jeopardised by the method of installation. No alteration that may invalidate the conditions of protection can be used.

9) Inspect that installations are kept clean and free from accumulation of dust, foreign particles and deleterious substances, and condensation;

10) Inspect that the surface temperatures of all equipment are appropriate to the type of protection being provided.

4.6 Inspection for Installations with Flammable Materials

Inspection for installations with flammable materials may include the following:-

1) Inspect correct design and erection methodologies in compliance to IEC 60364 / BS 7671 Part 5;

2) Inspect correct selection and quality control of construction material;

3) Inspect that apparatus/equipment such as lamps, fuses, cable and cable management are of correct type and rating in IEC 60364 / BS 7671 Part 5;

4) Inspect correct erection of installation;

5) Inspect that fire protection systems are installed;

6) Inspect correct buffer zones of flammable materials from the installations;

7) Inspect that integrity of the type of protection provided for the equipment is not jeopardised by the method of installation. No alteration that may invalidate the conditions of protection can be used.

8) Inspect installations are kept clean and free from accumulation of dust, foreign particles and deleterious substances, and condensation;

9) Inspect surface temperatures of all equipment are appropriate to the type of protection being provided.

4.7 Inspection for Installations with Confined Spaces

Inspection for installations with confined spaces may include the following:-

1) Inspect that design and erection methodologies are compliance to safety and health regulations;

2) Inspect correct erection of installation;

3) Inspect that confined space warning system is installed;

4) Inspect that emergency and exit route are properly planned and have adequate signage;

5) Inspect correct erection of emergency protection system.

6) Inspect that the installation is kept clean and free from accumulation of dust, foreign particles and deleterious substances, and condensation.

5. Testing Procedures

Testing should be carried out to confirm that the installation:-

1) Is in compliance with statutory and regulatory requirements, design intents, IEC 60364 and/or BS 7671, installations standards, etc.,

2) Is tested by Competent Person and with calibrated or verified test instruments;

3) Is safe, functioning and performing and at least meeting/exceed the design intent;

4) Is free of non – conformance prior to energisation and release to user;

5) Has all I & T works, functioning and performance data noted, measured and recorded for safe, effective and efficient operation and maintenance, and disposal of installation by users;

5.1 Elements of Safety, Functional and Performance Testing

Testing may include the following:-

1) Continuity of circuit conductors test (CCT));

2) Insulation resistance (IR) test;

3) Polarity test;

4) Earth electrode resistance (EER) test;

5) Earth fault loop impedance (EFLI) test;

6) Functions of residual current device (RCD) complying with IEC 61008 or 61009

7) Functions of all protective devices, except RCD;

8) Functions of all items of equipment/systems.

9) Lightning protection system

10) Circuitry check

11) Lighting installation

12) Measuring and Indicating Equipment

5.2 Continuity of Circuit Conductors Test (CCT)

CCT should be carried out on every conductor of every circuit in accordance with IEC 60364 / BS7671 Part 6–61.

CCT should be made by connecting together the neutral and protective conductors at the switchboard and check the earth and neutral conductor at every socket outlet. Lighting point terminals, etc., (Equipment Under Test (EUT))) by a CCT tester. The CCT tester should display a reading near zero.

It is recommended that CCT be carried out with a CCT test instrument with an electrical supply having a no-load voltage of 4 V_{dc} to 24 V_{dc} or 4V_{ac} to 24V_{ac}, and with a minimum current of 0.2A.

The Competent Person shall ensure that the temporary connection of the neutral and protective conductors is removed after completion of CCT.

5.3 Insulation Resistance (IR) Test

IR test should be carried out on every circuit and equipment in accordance with IEC 60364 / BS 7671 Part 6–61.

The Competent person shall ensure that the EUT and all equipment connected to the EUT could withstand the IR test voltage specified in IEC 60364/BS 7671: Part 6 Table 61A, without damage, especially latent damages such as degradation of insulation.

The IR test instrument shall be capable of supplying direct current (dc) test voltage specified in IEC 60364 / BS 7671 Part 6: Table 61A when loaded with 1 mA.

Every circuit and equipment should be IR tested separately. It is acceptable to divide large installations into manageable sections.

IEC 60364/BS 7671: Part 6 Table 61A

Nominal Circuit Voltage	Test Voltage (V_{dc})	Insulation Resistance (MΩ)
SELV and functional extra – low – voltage, when the circuit is supplied from a safety transformer (411.1.2.1) and also fulfill the requirements of 411.3.3	250	$\geq$ 0.25 @ +25 ^{o}C
Up to and including 500V, with the exception of the above cases	500	$\geq$ 25 @ +25 ^{o}C
Above 500V	1000	$\geq$ 25 @ +25 ^{o}C

The insulation resistance of EUT is satisfactory if each circuit, with ***appliances*** disconnected from the EUT, has an insulation resistance not less than the appropriate value given in IEC 60364 / BS 7671 Part 6: Table 61A or as specified in construction document, whichever is higher.

When the measured insulation resistance measured is near the minimum values (≤ Minimum insulation resistance +10%) or at a relatively low value considered abnormal when compared with manufacturer's technical specification, construction document or trade's practice or similar, remedial measures should be carried out on the EUT to improve the insulation resistance to acceptable value.

In carrying out the IR test:-

1) Wherever practicable, all lamps should be removed and all current using equipment and appliances such as uninterruptible power supply, variable speed drives, electric motors, IT equipment in the EUT should be disconnected from EUT and all local switches controlling lamps or other equipment should be closed. Where the removal of lamps and/or the disconnection of current using equipment is impracticable, the local switches controlling such lamps and/or current using equipment should be open;

2) Electronic devices and measuring equipment such as ammeters and power meters connected in the EUT should be isolated or short circuited where appropriate so that they are not damaged by the test voltage. When disconnecting the electronic devices and measuring equipment is not practical, the insulation resistance shall be measured between phases and neutral, connected together, to earth only; and

3) Where the EUT contain voltage sensitive devices, the IR test should measure the insulation resistance to earth with all live conductors (including the neutral) connected together.

The recommended sequence of IR test is as follows:-

1) Main switchboards with all outgoing sub–mains / circuits isolated;

2) Outgoing sub–mains / circuits of main switchboards with all protective circuit devices isolated;

3) Sub–switchboards with all outgoing circuits isolated;

4) Outgoing circuits of sub–switchboards with all protective circuit devices isolated;

5) Final distribution boards with all outgoing circuits isolated; and

6) Final outgoing circuits from final circuit boards with all apparatus such as light fittings, etc., disconnected;

7) Equipment.

Where apparatus is disconnected for IR test and the disconnected apparatus has exposed conductive parts which are connected to protective conductor, the IR between the exposed conductive parts and all live parts of the apparatus and EUT should be measured separately and the insulation resistance of the apparatus should be not less than 1 mega ohm.

5.4 Polarity Test

Polarity test should be carried out in accordance with IEC 60364/BS 7681 Part 6–6–61

Polarity test should be carried out to verify that:-

1) Every fuse and single-pole control and protective device is connected in the phase conductor only;

2) Centre-contact bayonet and Edison-type screw lampholders to IEC 60238 in circuits having an earthed neutral conductor, have their outer or screwed contacts connected to that neutral conductor; and

3) Wiring has been correctly connected to socket outlets and similar accessories.

5.5 Earth Electrode Resistance (EER) Test

EER test should be carried out in accordance with IEC 60364 / BS 7671 Part 6–6–61.

A four (Wenner method preferred) or three point EER tester should be used to measure earth electrode resistance.

Alternatively, if the installations are energised, EER can be measured by a loop impedance tester. A loop impedance tester should be connected between the phase conductor at the origin of the installation and the earth electrode with the test link open. The measured impedance value could be treated as the EER resistance.

5.6 Earth Fault Loop Resistance (EFLR) Test

EFLR test should be carried out in accordance with IEC 60364-6-61.

A phase–earth loop tester should be used to measure EFLR.

Prior to carry out the ELFR test, it is essential to:-

1) inspect that the earthing conductor and all relevant earth connections are in place;

2) Inspect that the equipotential bonding connection to electricity supplier’s earthing facilities is disconnected;

3) Isolate earth leakage protective devices for the duration of the EFLR test.

The Competent Person shall ensure that the earth leakage protective devices are re-connected after the EFLR test.

5.7 Functions of Residual Current Devices (RCD)

Functions of RCD complying with IEC 61008 / IEC 61009 should be tested in accordance with IEC 60364-6-61.

A RCD tester should be used to simulate an earth fault to verify effective operation of RCD, The RCD test should be made on the load side of the RCD between the phase conductor of the protected circuit and the associated circuit protective conductor with the load disconnected during the test.

The Competent Person shall ensure that the disconnected load is reconnected after the RCD test.

The RCD in-built test button should also be tested for proper functioning of RCD.

For general purpose RCD's: -

1) For a leakage test current to 50% of the rated tripping current, $I_{\Delta n}$, the EUT should not trip;

2) For a leakage test current 100% of the rated tripping current, $I_{\Delta n}$, the EUT should open in less than 300 ms.

For time delayed RCD which incorporates an intentional time delay, the RCD should trip within the time range from 130 ms to 500 ms for a leakage test current of 100% of the rated tripping current, $I_{\Delta n}$,

5.8 Functions of Electro – Mechanical/Mechanical Operated Devices

Functions of protective, switching and control electro–mechanical and mechanically operated devices, excluding RCD, such as miniature circuit breakers, molded case circuit breakers, air circuit breakers, fused switches, switch-fuses and protective relays, isolators, switches, socket outlets, emergency stops, indicating devices etc. should be checked mechanically by hand operation as appropriate.

Control equipment should be checked for correct utilisation categories.

Secondary Injection Test should be carried out to verify the overload and fault current protection characteristics of protection relays. Secondary injection test should be carry out by injecting alternating currents of different magnitudes into the relay terminals and measuring the relay operating time. The operating time should be checked against the manufacturer's data sheet and the construction document.

5.9 Lightning Protection System

Lightning protection system should be tested for continuity between air terminations, down conductors and earthing terminations. The measured resistance should be almost zero Ohm.

The continuity of the steel reinforcement should be tested if the steel reinforcement of the building structure is used as down conductors. The measured resistance should be almost zero Ohm.

The whole lightning protection system shall have a combined resistance to earth not exceeding 10 ohms.

The following additional inspection and/or check should be carried out: -

1) Check all connections such as sharp turning, terminations, tee off points and earth electrodes for tightness.

2) Inspect and ensure all down conductors at ground level for proper and sufficient insulation protection against flash – over hazards to people and livestock.

3) Inspect and ensure all earth pits for proper backfill and separating distance.

4) Inspect and ensure all earth electrodes and down conductors are clear of any combustible material such as diesel tanks and inflammable stores, etc.

5.10 Circuitry Check

Circuit check should be carried out on all circuits through switching operation to verify that the circuits are installed in accordance with the designated circuit. The circuit check should include the following:-

1) Switch ON/OFF the lighting circuit to verify that the lighting circuit is installed corresponding to the designated lighting circuit, lighting switch, protective device and labeling;

2) Switch ON/OFF the final power circuit and use a socket checker to check and verify that the socket outlet circuit is installed corresponding to the final power circuit, protective device, correct terminations and labeling;

3) Check the operation of residual current device (RCD) with an RCD tester;

4) Switch ON/OFF the general power circuit to verify that the circuit corresponds to the protective device;

5) Switch ON/OFF the main switch/isolator to ensure the corresponding circuit is properly controlled by the main switch/isolator;

6) Switch ON/OFF all sub-main and main distribution circuits, e.g. bus–ducts, cable feeders, underground cables, etc. to ensure the correct isolation of the connected circuit;

7) Switch ON/OFF changeover switches to ensure the changing over sequence corresponds to the design criteria;

8) Ensure all the protective devices perform properly against the designated circuit; and

9) Use an RCD tester to test and ensure the RCD is installed corresponding to the final power circuit.

5.11 Lighting Installation Test

Lighting installation test should include the following:-

1) Check all luminaries against the specified colour temperature, beaming angle of spot lamp and aiming angle for exterior floodlights.

2) Check that the aiming angle of external lighting or planter lighting shall not create glare or any obstructive light to external environment and/or neighborhood building users.

3) Measure the illumination level of lighting installation for individual areas/rooms to verify the light output. The EC shall confirm with the SP on the locations and height levels for carrying out the measurement of illuminance level. Presentation of the measurement result shall be in the form of marked up layout plan for the particular area.

4) Evaluate the lighting uniformity of the respective areas/rooms in terms of minimum to average illuminance ratio and/or any other uniformity ratio based on the measure illuminance results for individual areas/rooms

5) Test mechanically all grouping of luminaries by hand operation of the corresponding switches or timers.

6) Demonstrate proper control of the lighting installations for lighting installation with interface connection to building management system (BMS), or central control and monitoring system (CCMS) or similar central computer control system.

7) Test the functioning of occupying sensors for luminaries controlled by occupancy sensor.

8) Test dimmer function of luminaires controlled by daylight sensor within the preset range of illumination.

5.12 Measuring and Indicating Equipment Test

For measuring and indication equipment, such as ammeters and digital power meters, the test should include the following

1) Check the measurement categories;

2) Check the manufacturer's test and calibration report and certificate for functioning and accuracy;

3) Test the measurement, recording and interfacing functions comply with specifications and manufacturer's test and calibration or verification report;

4) Check proper functioning and interfacing, including digital and analogue outputs, connection to building management system (BMS), or central control and monitoring system (CCMS) or similar central computer monitoring system. Check proper functioning and interfacing, including digital and

analogue outputs by means of plugging in communication module for installation of DPM without external connection to BMS or CCMS.

5) Test the replacement mechanism to verify that the replacement of measuring and indicating equipment does not require the isolation of the respective switchboard.

6) Test the current transformer shorting blocks to ensure no open circuiting of the current transformers.

5.13 Busbar System Test

Busbar system Test should include the following:

1) Check nameplate information and labeling of busbar system;

2) Check adequacy of documentation from manufacturer;

3) Check the busbar system is type–tested;

4) Check the erection of busbar system;

5) Check the busbar system insulation resistance, continuity, polarity, earth fault loop impedance;

6) Check the long run busbar system phase transposition;

7) Check proper, positive earth connection and safe operation of plug–in tap–off units.

8) Check mechanical interlocks, quick fastening and quick releasing mechanism of the tap-off units;

9) Check all joints for abnormal rise in temperature by an infrared scanning.

5.14 Generator Test

Generator test should include the following:-

1) Check nameplate information and labeling of equipment;

2) Check adequacy of documentation from manufacturer;

3) Check the factory acceptance test on performance of the generator, such as step and full load test, fuel consumption, carbon monoxide emission;

4) Check erection of the generator, batteries system, fuel system and AMF board;

5) Check protective earthing and equipotential bonding system;

6) Check neutral earthing and installation earthing aspect for generator;

7) Check the generator room airflow, especially air intake and exhaust short–circuiting, and acoustic treatment requirements;

8) Check that all cabling works are done correctly and terminated properly;

9) Check that the batteries system is in normal floating charge conditions;

10) Site test the functioning and performance of the generator system similar to item 1);

11) Check all protective relays, automatic changeover schemes and automatic synchronizing scheme if applicable.

12) Measure noise level at a distance of 1 meter, unless specified otherwise in PP or by regulatory requirements, around the perimeter of generator room and the site boundary. The noise figure shall comply with the requirements of environmental regulations

5.17 Power Drive Systems

Power drive systems such as motors, adjustable speed drives and starters test should include the following:-

1) Check nameplate information and labeling of equipment;

2) Check adequacy of documentation from manufacturer;

3) Check the factory acceptance test on performance of the power drive systems and components;

4) Check erection of the power drive system and component;

5) Check protective earthing and equipotential bonding system;

6) Check the plant room ventilation;

7) Check that all cabling works are done correctly and terminated properly;

8) Check functions and performances;

9) Check voltage imbalance;

10) Check all protective relays, undervoltage protection and protection coordination;

11) Measure noise level at a distance of 1 meter, unless specified otherwise in PP or by regulatory requirements, around the perimeter of generator room and the site boundary. The noise figure shall comply with the requirements of environmental regulations

5.18 Low Voltage Switchgear (Switchboard) and Controlgear (Control Board) (LVSCB)

LVSCB test should include the following:-

1) Check nameplate information and labeling of equipment:-

2) Check adequacy of documentation from manufacturer;

3) Check switchgear and components arrangement against manufacturer's operation and maintenance manual;

4) Check enclosure for proper alignment, foundation fixing, and grounding and vermin entry;

5) Check all covers, sections and doors for paintwork and proper fit;

6) Check for smooth and proper movement of racking mechanisms, shutter, rollers, rails and guides;

7) Check proper alignment of the primary and secondary contacts;

8) Check proper installation of components, especially protective barriers and separators;

9) Check operation of all mechanical interlocks;

10) Check tightness of all bolted connections;

11) Check for correct phasing connection of bus bar and cabling works;

12) Check mechanical operations of mechanical and electro–mechanical devices such as circuit protective devices and contactors;

13) Check instrument transformers shorting mechanism;

14) Check protective and equipotential bonding system, especially equipotential bonding of doors and removal panels;

15) Check the following:-

    a. construction of type tested assembly;

    b. Form of separation;

    c. Power factor correction capacitor bank;

    d. Harmonic filter/reactors;

    e. Automatic changeover switch;

    f. Instrumentation and protection devices;

    g. Incoming/outgoing busbars and cables;

    h. Operating handles/keys.

6.0 Energisation of Installations

6.1 Inspection and Test before energisation of installations

Inspection and test before energisation of installations should include the following:-

1) Dielectric Test

Dielectric test should be carried out to verify the dielectric properties of the LVSCB in accordance with IEC 60439/61439.

2) Insulation resistance (IR) test

3) Secondary injection test

4) Primary injection test

Primary injection test should be carried out to prove the correct operation and coordination of protective devices or system when set at the agreed setting.

5) Polarity check and shorting check for Current Transformers

Polarity check for current transformers should be carried out to ensure that all current transformers are correctly connected.

Shorting check for current transformers should be carried out to ensure that all current transformer will be in closed–circuit conditions at all times

6) Functional and performance tests of all devices

Functional and performance test should be carried out to ensure that all devices operate properly as intended.

The equipment to be tested shall include, but not limited to, all circuit breakers, isolating switches, changeover switches, contactors, interlocking facilities, protective relays, earth leakage tripping devices, metering facilities and instruments.

7) Torqueing test

Torqueing test should be carried out by means of a torque wrench to ensure that all bolted joints are properly tightened

8) Contact resistance test

Contact resistance test should be carried out by means of "Ductor" tester to ensure that contacts and joints for switchgears, cables, busbars as well as the contacts and joints for outgoing cables and busbars are maintained in good condition.

9) Infrared scanning of joints, cable lugs and power devices

Infrared scanning of joints, cable lugs and power devices should be carried out to ensure they are installed correctly

10) Site inspection prior to energisation

The installation should be inspected, house–kept, with all proper and necessary fire and safety protection system such as insulating mat and CPR chart in place and properly secured;

11) Notification of energisation

The EC should inform the SP that the site is ready for energisation and submit all documentation which is pre–requisite to energisation to SP and to statutory body and/or electricity provider for approval.

The EC shall arrange for settlement of all payment required prior to issuance of permit to energisation.

The EC shall arrange for all site inspection by statutory body and/or electricity provider prior to issuance of permit to energisation.

The EC shall arrange for all energisation procedures. EC shall ensure all energisation reports are submitted to the SP for review, approval and endorsement

6.2 Inspection and test after Energisation of Installation

Energisation and inspection and test after energisation of the installation should be carried out in stages. The preferred sequence of work should be from the main switchboard to final circuit / installation equipment and end user equipment

1) Nominal voltage measurement including phase–to–phase, phase–to–neutral, phase–to–protective conductor voltage, and neutral–to–earth nominal voltage tests;

2) Phase sequence test on each and every circuit;

The nominal voltage at no load shall comply with the requirements of IEC 60038.

6.3 Equipment and Appliances Test

Equipment and appliances test should be done where the nominal voltage at no load is checked and complying with IEC 60038

Equipment and appliance, such as indicating and measurement instrument, light fittings, fans, should be carried out in accordance with relevant product standards and manufacturer's specifications.

6.4 Any Other Tests that are Considered Necessary to Meet the Design and Erection Intent

The EC should submit full details of testing requirements as recommended by the relevant manufacturer in the PP and submit to the SP for review and approval.