Electricity Distribution

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Company Directive

STANDARD TECHNIQUE: TP21OC/0

Earthing System Measurements - Part C
Equipment Earth Connections

Summary
This Standard Technique defines the requirements for verifying equipment earth connections on earthing systems which are to be owned or adopted by National Grid Electricity Distribution.

This document does not apply to earth connections between a substation and a terminal tower.

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Implementation Date: **April 2024**

Approved by

Carl Ketley-Lowe
Head of Engineering Policy

Date: **17th April 2024**

Target Staff Group	**Network Services Teams, Engineering Trainers & ICPs**
Impact of Change	**GREEN - The change has no immediate impact on working practices or has been aligned to current working practices – Communication via a monthly update of changed policy. Team Manager discretion on how the changes are communicated to the team.**
Planned Assurance checks	**Policy Assurance Specialists shall confirm whether the requirements have been complied with during their sample checking of completed jobs**

IMPLEMENTATION PLAN

Introduction

This Standard Technique defines the requirements for verifying equipment earth connections on earthing systems which are to be owned or adopted by National Grid Electricity Distribution.

Main Changes

This document is a new ST, however, it replaces parts of TP21O.

Impact of Changes

This Standard Technique is relevant to staff, Contractors and Independent Connection Providers involved with the design / assessment of earthing systems.

Implementation Actions

Managers should notify relevant staff that this Standard Technique has been published.

There are no retrospective actions.

Implementation Timetable

The document can be implemented once being read and understood and can be utilised from issue.

REVISION HISTORY

Document Revision & Review Table		
Date	**Comments**	**Author**
April 2024	• New document	Mark Kneebone

Contents

1.0 INTRODUCTION

This Standard Technique defines the requirements for verifying equipment earth connections on earthing systems which are to be owned or adopted by National Grid Electricity Distribution.

It is essential to verify that each item of plant and equipment is effectively connected to the earth electrode system following the construction, modification or repair of an electrical installation.

This Standard Technique shall be applied to all NGED substations at 33kV and above. The measurement procedure can be optionally applied to substations at lower voltages where required.

This document does not apply to earth connections between a substation and a terminal tower.

2.0 DEFINITIONS

For the purpose of this document the following definitions are employed:

TERM	DEFINITION
Earth Electrode	A conductor or group of conductors in direct contact with the soil and providing an electrical connection to earth.
Earthing Conductor	A protective conductor which connects plant and equipment to an earth electrode.
Earthing System	The complete interconnected assembly of earthing conductors and earth electrodes (including cables with un-insulated sheaths).
Earth Potential	The difference in potential which may exist between a point on the ground and remote reference earth.
Reference Earth	Part of the Earth, the electric potential of which is conventionally taken as zero.
Electrical Installation	An assembly of associated electrical equipment to fulfil a specific purpose. For example: a 132kV, 66kV or 33kV substation; a ground mounted distribution substation; auxiliary equipment on an earthed pole; etc

3.0 REFERENCES

This document makes reference to, or should be read in conjunction with, the documents listed below. The issue and date of the documents listed below shall be those applicable at the date of issue of this document, unless stated otherwise.

3.1 British Standards

NUMBER	TITLE
BS EN 50552	Earthing of power installations exceeding 1 kV a.c.

3.2 Energy Networks Association

NUMBER	TITLE
ENA TS 41-24	Guidelines for the design, installation, testing and maintenance of main earthing systems in substations

4.0 OVERVIEW OF EQUIPMENT EARTH CONNECTION MEASUREMENTS

It is essential to verify that each item of plant and equipment is effectively connected to the earth electrode system following the construction of a new electrical installation, or modification of an existing one.

Plant and equipment must be sufficiently bonded to the earthing system to ensure correct operation and that the potential difference created under fault conditions is within the safe limits.

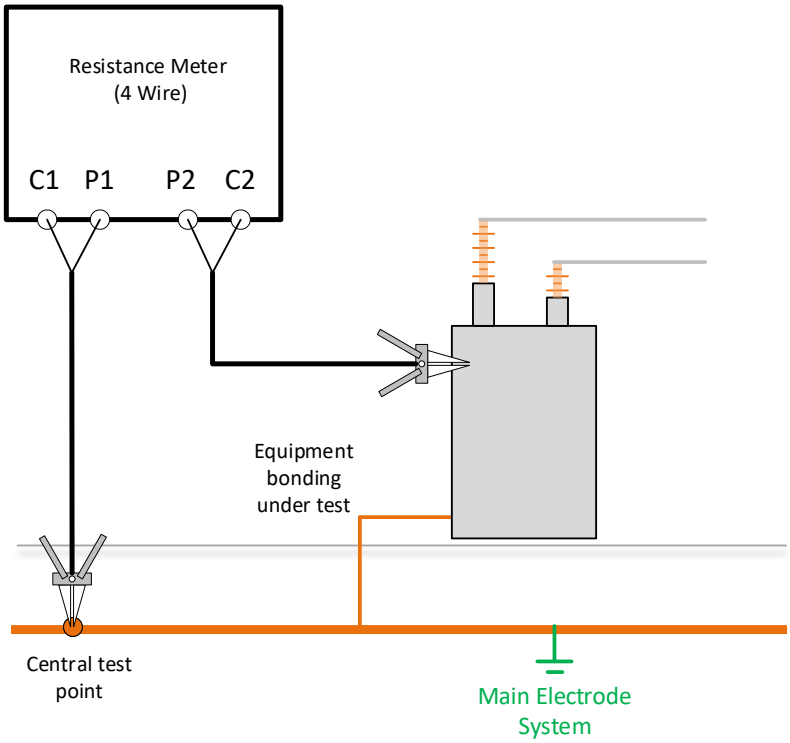
A sufficient bond between equipment and the earthing system can be confirmed if the resistance between the central test point (or points) on the main earthing system and individual items of earthed equipment does not exceed 20mΩ.

5.0 REQUIREMENTS

5.1 Method

The procedure is based upon the principle of measuring the resistance between a central test point (or points) on the main earthing system and individual items of earthed equipment using a four-terminal portable micro-ohmmeter and associated insulated test leads and test clamps/clips/probes.

Figure 1: Test Arrangement



Once it has been established that an item of plant in adequately bonded, it may be itself be used as a new central test point to avoid the use of unduly long test leads when testing adjacent equipment.

It is necessary to measure in the μΩ or mΩ range with a recommended injection current of at least 100mA. The probable path of the injected current should be considered and, where the substation uses a bus-zone protection scheme, care should be taken to ensure that any test current does not produce enough current to operate protection systems.

5.2 Restrictions

This test method shall not be used to check the bonding between a substation and a terminal tower.

Care must be taken to ensure that the path of test current cannot operate system protection. Joint resistance measurement shall not be performed:

- Across switchgear framework/cubicles/bonding bar and substation earth electrode where the switchgear is fitted with frame-leakage protection.

5.3 Interpretation Of Results

The expected resistance between two effectively bonded points in an earthing system should be low. It is determined by:

- Series resistance of the earthing conductor
- Series/parallel resistance of earth electrode
- Series/parallel resistance of joints/connections.

It will largely depend on the length of conductor/electrode involved and its cross-sectional area. Using the resistance per meter for the appropriate conductor below an anticipated bonding resistance can be calculated. An addition of 50μΩ for each joint should be included in the calculation. Table 1 below gives example values.

Table 1: Conductor Resistance per meter at 20°C

Conductor	**Resistance per meter without joints (μΩ)**
50mm x 6mm copper tape	57
50mm x 4mm copper tape	86
50mm x 3mm copper tape	115
25mm x 4mm copper tape	172
25mm x 3mm copper tape	229
120mm^2 stranded copper	143
70mm^2 stranded copper	254
35mm^2 stranded copper	509

Worked example:

A circuit breaker is bonded to the earth electrode system using 20m of 50mm x 4mm copper tape with two joints in the bonding conductor.

(20m x 86μΩ) + (2 joints x 50μΩ) = 1,820μΩ or 1.82mΩ

Consequently, bonding measurements should be in the high micro-ohms or low milliohms range rather than ohms.

If the measured value is less than 20mΩ then this implies adequate bonding, a measured value above this threshold will require further investigation.

5.4 Sources of Measurement Error and Variation

Paint, scale or oxide coatings on conductors may affect the accuracy of the resistance measurement. Conductors shall be abraded to expose clean surfaces for connections.

Micro-ohmmeters are designed for a specific lead resistance. If higher resistance leads are used the injected current may be reduced and may cause signal-noise problems that may reduce the accuracy and/or repeatability of the resistance measurement.

When using an adjacent item of plant as a known good test point additional resistance may be included in the measurement. In the event that the pass limit is exceeded the measurement should be repeated between the item of plant under test and the main earthing system.

5.5 Test Results

The following spreadsheet shall be employed for recording the results of Equipment Earth Connections.

TP21OC Test Results

The measured value of equipment connection along with its reference should be recorded in the construction/project file.

Figure 2: Example test results sheet

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EQUIPMENT EARTH CONNECTION MEASUREMENTS (TP21OC)

General Details

Location Reference:		12/1234 Substation Name
Date:		01/03/2024
Person Undertaking Measurement:		Mark Kneebone
Test Instrument	**Make**	Megger
	Model	DLRO10
	Serial No.	SN1234

Pass/Fail Limits

Equipment to Earthing System Measurement	Maximum Resistance
	20mΩ

Equipment to Equipment Measurement	Maximum Resistance
	20mΩ

Test Results

Equipment Reference	Measurement (mΩ)	Pass / Fail
T1	8	Pass
T2	8	Pass
1SO	10	Pass
1L5	10	Pass
2L5	10	Pass
3L5	10	Pass

6.0 RISK ASSESSMENT & METHOD STATEMENT

6.1 Risk Assessment

HAZARD	PROBABILITY	CONTROL MEASURES
Electric shock or burns as a result of earth potential rise	Low	• No testing if lightning is likely • No testing whilst fault switching is being undertaken • No testing if insulators are damaged • Use of insulated mats, gloves and footwear
Electric shock or burns from test voltages / currents	Low	• One person in control of testing • Radio communication between earth tester operator and personnel who move remote current and voltage probes (who may be out of sight / earshot)
Electric shock or burns from induced voltages from nearby power lines	Low	• Avoid test probe route parallel with overhead lines, if possible • If not possible, maximize separation between test probe route and overhead line
Electric shock or burns due to damaged test equipment or leads	Low	• Ensure condition of test equipment and leads are satisfactory prior to use
Slips, trips and falls	Medium	• Maintain awareness of surroundings whilst undertaking measurements

6.2 Method Statement

6.2.1 Equipment

The following test equipment is required in order to perform joint resistance measurements:

Figure 3: Measurement instruments

- Four-terminal portable micro-ohmmeter (e.g. Megger DLRO10)
- Insulated test leads – minimum 1.5mm^2
- Test clamps, clips, probes
- Emery cloth or wire brush

6.2.2 Test Arrangement

Figure 1 shows the test arrangement to be employed for carrying out equipment bonding measurements.

6.2.3 Safety Precautions

When performing equipment bonding measurements, the following precautions shall be taken:

- Comply with applicable safety rules
- Conduct Site Specific Risk Assessment and communicate risks to people at risk in accordance with ST: HS20A.
- All testing under immediate control of one person.
- Communication between earth tester operator and personnel who move 'remote' trailing leads.
- Personnel wear Class 1 rubber gloves and the additional protection of insulating safety footwear.
- No testing if lightning likely (e.g. lightning risk warning Category 1).

- CONTROL notified and no work if relevant fault switching planned/under way (e.g. either on substation under test or, where cable is present, ANY point on the network fed from the source primary substation AND INCLUDING any primary substation run in parallel).

- If relevant lightning or fault switching occurs while testing, the testing must cease immediately.

- Ensure condition of test equipment is satisfactory prior to use.

6.2.4 Method

1	IDENTIFY	earth conductors to test.
2	INFORM	CONTROL before commencing work. Confirm risk of lightning not Category 1 and that no fault switching will be performed. Ensure earth conductor to test has visible connection to earth and check visually that system insulators associated with earthed structure where earth connection will be made are undamaged. If in doubt then prove the earthed structure DEAD using procedure in ST: OS4B.
3	PLACE	micro-ohmmeter between the earth conductors under test.
4	SWITCH	the micro-ohmmeter on and allow to self calibrate/stabilise as per manufacturers instructions.
5	REMOVE	scale/oxide coating to expose clean surfaces for connection if copper conductor.
6	CONNECT	the C1 and P1 terminals of the micro-ohmmeter to the central test point as shown in Figure 1 by the test leads. NOTE Micro-ohmmeters are designed for a specific lead resistance – if higher resistance leads are used the injected current may be reduced and may cause signal-noise problems that may reduce the accuracy and/or repeatability of the resistance measured. NOTE It is important that the leads are not commoned at the micro-ohmmeter terminals as the lead resistance would be included in the measurement. Furthermore, do not connect the potential probe to the current probe if separate test leads are used.

7	CONNECT	the C2 and P2 terminals of the micro-ohmmeter to the equipment under test as shown in Figure 1. NOTE It is important that the leads are not commoned at the micro-ohmmeter terminals as the lead resistance would be included in the measurement. Furthermore, do not connect the potential probe to the current probe if separate test leads are used.
8	MEASURE	the resistance. Select a suitable scale as necessary. If the micro-ohmmeter has the facility to reverse the test current polarity then re-test – in this case calculate the average of the two measurements for interpretation.
9	SWITCH	the micro-ohmmeter off.
10	DETERMINE	if the equipment bonding is satisfactory.
11	RECORD	the resistance of the equipment bond and its location in the construction/project file/.
12	REPEAT	from item 7, radially, for all nearby earthing conductors, as required.
13	REPEAT	from item 1 for other reference points until whole site checked, as required.

APPENDIX A

SUPERSEDED DOCUMENTATION

This is a new document and no document is superseded by its issue.

APPENDIX B

RECORD OF COMMENT DURING CONSULTATION

ST: TP21OC/0 - Comments

APPENDIX C

ANCILLARY DOCUMENTATION

POL: TP21 - Fixed Earthing Systems

APPENDIX D

KEY WORDS

Earth; Earthing; Measurement; Test; Bonding; Equipment Connections