Electricity Distribution

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Company Directive

STANDARD TECHNIQUE: TP21OG/0

Earthing System Measurements - Part G Joint Resistance

Summary

This Standard Technique defines the requirements for carrying out joint resistance measurements on earthing systems which are to be owned or adopted by National Grid Electricity Distribution.

Author: **Mark Kneebone**

Implementation Date: **April 2024**

Approved By:

Carl Ketley-Lowe
Head of Engineering Policy

Date: **11th 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 carrying out joint resistance measurements 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 carrying out on-site joint resistance measurements for earthing systems which are to be owned or adopted by National Grid Electricity Distribution.

Joint resistance testing in earthing conductors is vital to ensure effective low impedance grounding by identifying high resistance joints. By verifying joint resistance we guarantee a reliable path for fault currents.

Whenever a joint is made to a measurement of the resistance across an earth conductor joint is required to check its electrical integrity. This is normally performed for every joint created at a new substation prior to commissioning. It is also carried out during periodic maintenance assessments.

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.

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 Impedance	The impedance between the earthing system and remote reference earth.
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.

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

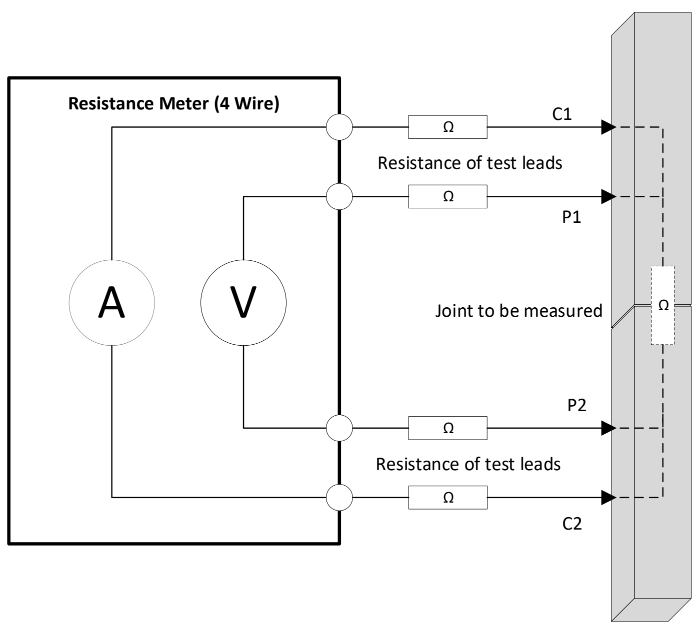
NUMBER	TITLE
ENA TS 41-24	Guidelines for the design, installation, testing and maintenance of main earthing systems in substations

4.0 OVERVIEW OF JOINT RESISTANCE TESTING

Principle of measurement - 4-Wire Measurements.

A resistance measurement is usually made by injecting a current through the item under test whilst measuring the voltage across the item. The resistance can be calculate by using Ohm's law (R = V / I).

Figure 1: 4-Wire Test Arrangement



Joints in earthing systems are inherently low impedance and are typically measured in μΩ. As such we require a measurement that excludes the contact resistance of the probes and series lead resistance. This can be achieved using a 4-wire measurement.

A 4-wire measurement injects a known current into the test sample through two leads, usually identified as C1 and C2. Concurrently, two probes, normally referred to as P1 and P2, measure the potential across the sample. The instrument then performs an internal calculation to determine the resistance of the test sample.

Since no current is conducted in P1 & P2 any contact or test lead resistance will not affect the voltage measurement. The measured injection current following through C1 & C2 test leads will equal the current flowing through the test sample irrespective of any contact or test lead resistance.

5.0 REQUIREMENTS

5.1 Method

Joint resistance shall be measured using a four-terminal portable micro-ohmmeter and associated insulated test leads and test clamps/clips/probes.

The micro-ohmmeter shall be capable of injecting a test current of 10 A minimum.

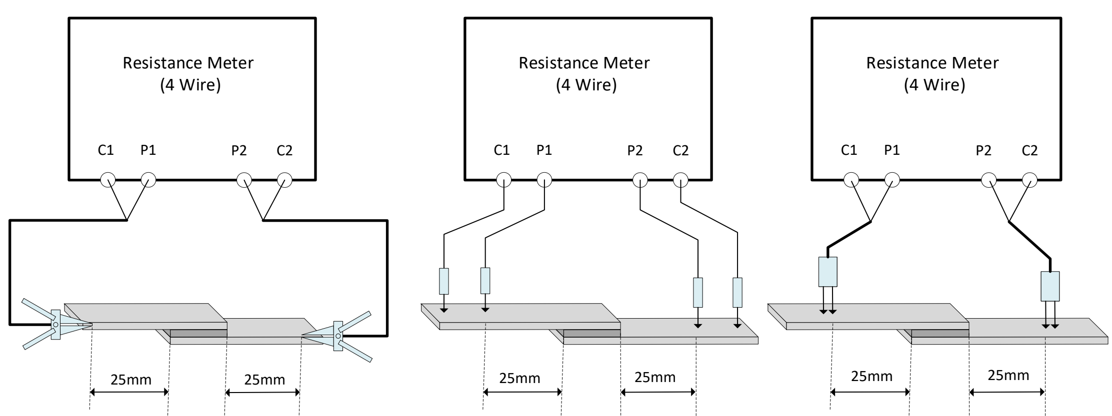
Where the tester provides four discrete test probes the potential probes (P1 & P2) should be inboard of the current probes (C1 & C2), i.e. the potential probes should be closer to the joint under test. Ideally, the connectors should be no more than 25 mm either side of the joint. A suitable scale should be selected on the instrument for measurement in the micro-ohm range.

These requirements apply to bolted, brazed and welded joints and are applicable for all sites i.e. Grid & Primary substations as well as optionally applicable to ground-mounted and pole-mounted distribution locations. Note that these measurements do not check the mechanical integrity of welded, brazed or bolted joints, nor does it check for voids inside welded or brazed joints.

5.2 Test Arrangement

Figure 2Figure 2: Joint Resistance Test Arrangement shows the test arrangement to be employed for carrying out joint resistance measurements.

Figure 2: Joint Resistance Test Arrangements



5.3 Restrictions

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.
- Across any CT.

5.4 Interpretation of Results

A 'good' joint will have a measured resistance that should not significantly exceed that of an equivalent length of conductor without a joint. For a given length of conductor the resistance depends on the cross-sectional area. Ideally, the resistance with a joint should not exceed 150% of that for the same length (and same cross-sectional area) without a joint. The upper threshold for acceptance of a new joint is that the resistance with a joint shall not exceed 175% of that for the same length (and same cross-sectional area) without the joint.

5.4.1 New Joints and bolted connections

Table 1 below shows the resistance for various typical cross-sectional areas for a 50mm length of conductor without a joint together with the maximum acceptable resistance for a jointed section (new joint).

Table 1: Conductor and New Joint Resistances at 20ºC

Conductor (50mm Length)	Resistance Without joint (μΩ)	Max Resistance With New Joint (μΩ)
50mm x 6mm copper tape	3	5
50mm x 4mm copper tape	4	8
50mm x 3mm copper tape	6	10
25mm x 4mm copper tape	9	15
25mm x 3mm copper tape	11	20
120mm^2 stranded copper	7	13
70mm^2 stranded copper	13	22
35mm^2 stranded copper	25	45
U Bolt Connection	-	20
Bolted copper to aluminium tape, or aluminium to aluminium tape	-	20
Bolted copper to steel or aluminium structure	-	20
Bolted joints onto equipment earth terminals & earth bars	-	10

5.4.2 Existing Joints and bolted connections

For an existing joint some deterioration will occur. A general limit of 50µΩ for the joint itself is set as the threshold for deciding whether an existing joint shall be remade. An exception is made for 35mm² stranded copper where a limit of 100µΩ shall apply. NB If the measured value exceeds the appropriate limit then the resistance of the joint itself may be deduced approximately by measuring the same length of conductor but with no joint and deducting that figure from the figure that includes the joint.

5.5 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.

Ambient temperature can also have an impact on the measured resistance. The resistance of copper varies with temperature, as shown in
Table 2Table 1 below.

Table 2: Effect of Temperature on Copper Resistance

Temperature (ºC)	Resistance (Ω) as a percentage of the value at 20ºC
5	94%
10	96%
15	98%
20	100%
25	102%

5.6 Test Results

The following spreadsheet shall be employed for recording the results of a Joint resistance tests.

TP21OG Test Results

The measured value of each tested joint along with its location should be recorded in the construction/project file. A plan or diagram identifying the joint reference and its location is require to support the test result spreadsheet.

Figure 3: Example test results sheet with supporting diagram

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JOINT RESISTANCE MEASUREMENT (TP21OG)

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

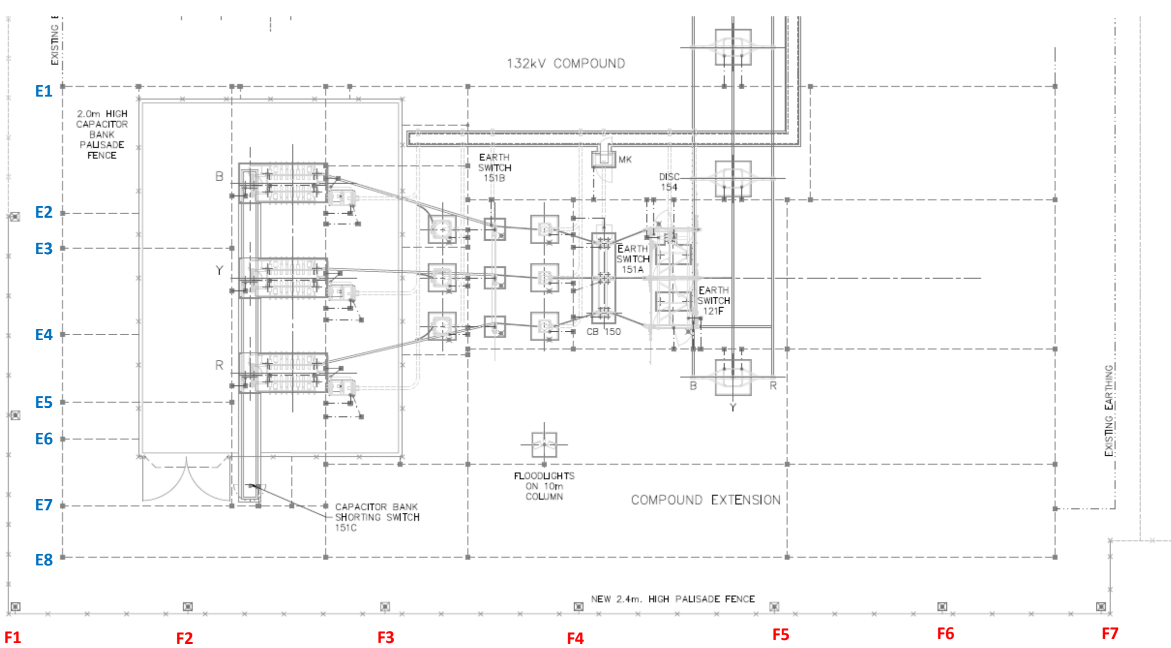
Pass/Fail Limits

Conductor	Maximum Resistance (µΩ)
50mm x 6mm copper tape	5
50mm x 4mm copper tape	8
50mm x 3mm copper tape	10
25mm x 4mm copper tape	15
25mm x 3mm copper tape	20
120mm² stranded copper	13
70mm² stranded copper	22
35mm² stranded copper	45

Conductor	Maximum Resistance (µΩ)
U Bolt Connection	20
Bolted copper to aluminium tape, or aluminium to aluminium tape	20
Bolted copper to steel or aluminium structure	20
Bolted joints onto equipment earth terminals & earth bars	10

Test Results

Joint Reference	Measurement (µΩ)	Pass / Fail
E1	8	Pass
E2	8	Pass
E3	8	Pass
E4	8	Pass
E5	8	Pass
E5	8	Pass
E6	8	Pass
E7	8	Pass
E8	8	Pass
F1	16	Pass
F2	17	Pass
F3	16	Pass
F4	17	Pass
F5	18	Pass
F6	17	Pass
F7	16	Pass



6.0 RISK ASSESSMENT & METHOD STATEMENT

6.1 Risk Assessment

HAZARD	PROBABILITY	CONTROL MEASURES
Electric shock or burns from test voltages / currents	Low	• One person in control of testing
Electric shock or burns from fault current	Low	• No testing whilst fault switching is being undertaken • No testing if insulators are damaged
Electric shock or burns from lightning	Low	• No testing if lightning is likely
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 4: 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 Safety Precautions

When performing joint resistance measurements, the following precautions shall be taken:

- 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.
- No testing if lightning likely (e.g. lightning risk warning Category 1).
- If relevant lightning or fault switching occurs while testing, the testing must cease immediately.
- Personnel wear Class 1 rubber gloves and the additional protection of insulating safety footwear.
- Ensure condition of test equipment is satisfactory prior to use.

6.2.3 Method

1	PLACE	micro-ohmmeter at test position.
2	SWITCH	the micro-ohmmeter on and allow to self-calibrate/stabilize as per manufacturer's instructions.
3	REMOVE	scale/oxide coating to expose clean surfaces for connections.
4	CONNECT	the four terminals of the micro-ohmmeter to the joint under test by the correct test leads for the instrument - see Figure 2: Joint Resistance Test Arrangements. 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 ensure that the potential probes (P1 & P2) are closer to the joint than the current probes (C1 & C2). NOTE ensure that the potential probes (P1 & P2) are closer to the joint under test than the current probes (C1 & C2). 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.
5	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.
6	SWITCH	micro-ohmmeter off.
7	DETERMINE	if the joint is satisfactory.
8	RECORD	the resistance of the joint and its location in the construction/project file/Crown.

APPENDIX A

SUPERSEDED DOCUMENTATION

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

APPENDIX B

RECORD OF COMMENT DURING CONSULTATION

Comments – ST: TP21OG/0

APPENDIX C

ANCILLARY DOCUMENTATION

POL: TP21 - Fixed Earthing Systems

APPENDIX D

KEY WORDS

Earth; Earthing; Measurement; Test; Resistance; Joint, Ductor;