

## **Company Directive**

### **STANDARD TECHNIQUE : TP21A/2**

#### **Relating to Safety Limits for Touch and Step Voltages - Earthing System Design/Assessment**

##### **Policy Summary**

This document defines safety limits for touch and step voltages. These are based on ENA TS 41-24 and the underlying assumptions. These limits shall be used in the earthing system design/assessment of major substations (ST:TP21B/1 and EE SPEC:89/1 refer) and in other assessments of touch and step voltage (e.g. generic design of 11kV earthing systems).

**Author:** S Scarbro

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**Approved by** 

**Policy Manager**

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## **1.0 INTRODUCTION**

- 1.1 This document defines safety limits for touch and step voltages in tabular form. These are based on curves in ENA TS 41-24 and the underlying assumptions. These safety limits shall be used in the earthing system design/assessment of major substations (ST:TP21B/1 and EE SPEC:89/1 refer) and in other assessments of touch and step voltage (e.g. generic design of 11kV earthing systems).
- 1.2 The rise of earth potential associated with current passing through an earthing system under fault conditions can present an electric shock hazard.
- 1.3 Potential difference between parts of the human body causes current to flow. There is a risk of fatal electric shock if the current flows for sufficient time to cause ventricular fibrillation<sup>1</sup> of the heart. IEC 60479-1 defines a series of time-current curves for judging whether this will occur. Curve  $c_1$ , which gives the current-time relationship for virtually no risk of ventricular fibrillation, is used by ENA TS 41-24 to derive permissible touch (voltage between hand and feet) and step voltages (voltage between feet) for conditions with and without a high-resistivity surface covering.
- 1.4 It is possible to control touch and step potentials to 'safe' levels by design. Standard Techniques in the ST:TP21 series and EE SPEC:89/1 refer to this document.

## **2.0 CURRENT AND VOLTAGE SAFETY LIMITS**

- 2.1 Table 1 defines safety limits for use in assessment of the acceptability of hand-to-foot/feet touch voltages and foot-to-foot step voltages. Table 2 defines safety limits for use in the assessment of the acceptability of hand-to-hand touch voltages.

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<sup>1</sup> A state of the heart in which the heart muscle cells lose their synchronism, resulting in the interruption of the heart's pumping action.

| Duration of Current Flow (s) | Curve c <sub>1</sub> Body Current Limit,<br>I <sub>B</sub> (mA) | Touch Voltage Limit (V) |           |              |                     | Step Voltage Limit (V) |           |              |                     |
|------------------------------|-----------------------------------------------------------------|-------------------------|-----------|--------------|---------------------|------------------------|-----------|--------------|---------------------|
|                              |                                                                 | Bare Soil               | Chippings | 100mm Tarmac | Dry Indoor Concrete | Bare Soil              | Chippings | 100mm Tarmac | Dry Indoor Concrete |
| 0.2                          | 344                                                             | 1031                    | 1375      | 6192         | 2064                | 3094                   | 4469      | 23736        | 7224                |
| 0.3                          | 246                                                             | 738                     | 984       | 4428         | 1476                | 2214                   | 3199      | 16974        | 5166                |
| 0.35                         | 199                                                             | 597                     | 797       | 3582         | 1194                | 1792                   | 2588      | 13731        | 4179                |
| 0.4                          | 153                                                             | 459                     | 613       | 2754         | 918                 | 1378                   | 1991      | 10557        | 3213                |
| 0.5                          | 98                                                              | 295                     | 394       | 1764         | 588                 | 887                    | 1281      | 6762         | 2058                |
| 0.6                          | 75                                                              | 226                     | 301       | 1350         | 450                 | 678                    | 980       | 5175         | 1575                |
| 0.7                          | 63                                                              | 190                     | 254       | 1134         | 378                 | 571                    | 825       | 4347         | 1323                |
| 0.8                          | 56                                                              | 169                     | 225       | 1008         | 336                 | 507                    | 732       | 3864         | 1176                |
| 0.9                          | 52                                                              | 156                     | 208       | 936          | 312                 | 467                    | 675       | 3588         | 1092                |
| 1                            | 50                                                              | 150                     | 200       | 900          | 300                 | 450                    | 650       | 3450         | 1050                |
| 3                            | 40                                                              | 120                     | 160       | 720          | 240                 | 360                    | 520       | 2760         | 840                 |
| 10                           | 40                                                              | 120                     | 160       | 720          | 240                 | 360                    | 520       | 2760         | 840                 |

**Table 1 – Hand-to-foot/feet touch voltage and foot-to-foot step voltage limits - 50Hz  
- IEC 60479-1 Curve c<sub>1</sub>**

NOTE For chipping specification see EE SPEC 89.

| Duration of Current Flow (s) | Curve c <sub>1</sub> Body Current Limit, left hand-feet, I <sub>B</sub> (mA) | Curve c <sub>1</sub> Body Current Limit, hand-hand, I <sub>B</sub> (mA) | Hand-to-Hand Touch Voltage Limit (V) |
|------------------------------|------------------------------------------------------------------------------|-------------------------------------------------------------------------|--------------------------------------|
| 0.2                          | 344                                                                          | 860                                                                     | 1147                                 |
| 0.3                          | 246                                                                          | 615                                                                     | 820                                  |
| 0.35                         | 199                                                                          | 497.5                                                                   | 663                                  |
| 0.4                          | 153                                                                          | 382.5                                                                   | 510                                  |
| 0.5                          | 98                                                                           | 245                                                                     | 327                                  |
| 0.6                          | 75                                                                           | 187.5                                                                   | 250                                  |
| 0.7                          | 63                                                                           | 157.5                                                                   | 210                                  |
| 0.8                          | 56                                                                           | 140                                                                     | 187                                  |
| 0.9                          | 52                                                                           | 130                                                                     | 173                                  |
| 1                            | 50                                                                           | 125                                                                     | 167                                  |
| 3                            | 40                                                                           | 100                                                                     | 133                                  |
| 10                           | 40                                                                           | 100                                                                     | 133                                  |

**Table 2 – Hand-to-hand touch voltage limits – 50Hz – IEC 60479-1 Curve c<sub>1</sub>**

### 3.0 BACKGROUND

3.1 In converting body current limits to voltage limits the following assumptions have been made:

- Body resistance = 1000 ohm
- Shoe resistance = 4000 ohm/shoe
- High resistivity chippings resistance = 2000 ohm/shoe
- Tarmac = 30,000 ohm/shoe
- Dry concrete = 6,000 ohm/shoe.

3.2 The formulae used are:

- Touch voltage bare soil =  $I_B \times (1000 + 4000/2)$  V =  $3000I_B$  V
- Touch voltage chippings =  $I_B \times (1000 + (4000+2000)/2)$  V =  $4000I_B$  V
- Touch voltage tarmac =  $I_B \times (1000 + (4000+30000)/2)$  V =  $18000I_B$  V
- Touch voltage dry concrete =  $I_B \times (1000 + (4000+6000)/2)$  V =  $6000I_B$  V
- Step voltage bare soil =  $I_B \times (1000 + 4000 + 4000)$  V =  $9000I_B$  V
- Step voltage chippings =  $I_B \times (1000 + 4000 + 4000 + 2000 + 2000)$  V =  $13000I_B$  V
- Step voltage tarmac =  $I_B \times (1000 + 4000 + 4000 + 30000 + 30000)$  V =  $69000I_B$  V

- h) Step voltage dry concrete =  $I_B \times (1000 + 4000 + 4000 + 6000 + 6000) \text{ V} = 21000I_B \text{ V}$
  - i) Touch voltage hand-to-hand =  $I_B/F \times 1000/BF \text{ V}$  where F is the heart current factor (i.e. 0.4) and BF the body factor ratio of hand-both feet body impedance to hand-hand body impedance (i.e. 0.75).
- 3.3 The above includes the method underlying the touch and step voltage limit curves in ENA TS 41-24 which only cover bare soil and chipping cases. Consequently the values presented in Table 1 are the same. Interpretation is simplified by presentation in tabular form.
- 3.4 The same underlying approach has been used to produce safety limits for hand-to-hand touch voltages and foot-to-foot step voltages for tarmac and dry indoor concrete surfaces and also hand-to-hand touch voltages.

## **APPENDIX A**

### **SUPERSEDED DOCUMENTATION**

This document supersedes ST:TP21A/1 dated July 2006 which should now be withdrawn.

## **APPENDIX B**

### **ASSOCIATED DOCUMENTATION**

|                              |                                                                                                          |
|------------------------------|----------------------------------------------------------------------------------------------------------|
| ST:TP21B/1                   | Design and installation of fixed earthing systems - major substations                                    |
| EE SPEC:89/1                 | Fixed earthing systems for major substations                                                             |
| ENA Technical Standard 41-24 | Guidelines for the design, installation, testing and maintenance of main earthing systems in substations |
| IEC 60479-1                  | Effects of current passing through the human body                                                        |

## **APPENDIX C**

### **IMPLEMENTATION OF POLICY**

Immediate.

No retrospective action is required because of the revision of the Standard Technique.

## **APPENDIX D**

### **IMPACT ON COMPANY POLICY**

This Standard Technique is relevant to staff or Contractors involved with the design/assessment of earthing systems for safe touch and step voltage (e.g. by Primary System Design for major substations).

This revision adds safety limits for two other types of ground surface – tarmac and dry indoor concrete – and also adds limits for hand-to-hand contact.

## **APPENDIX E**

### **KEY WORDS**

Earthing, Electric shock, Step Voltage, Touch Voltage.