HAZARD ASSESSMENT GUIDE

ASSESSMENT OF RISK OF EPR AND INDUCED VOLTAGE HAZARD TO TELECOMMUNICATION NETWORKS

NZCCPTS

Draft
Prepared March 2023
Not finalised for publication.

The New Zealand Committee for the Co-ordination of Power and Telecommunication Systems Inc. (NZCCPTS)

The New Zealand Committee for the Co-ordination of Power and Telecommunication Systems was established in 1985 following the increasing need to implement efficient cost-effective measures for the limitation of hazard and interference to Power and Telecommunications Systems and Personnel.

Such measures not only require the determination of optimum engineering solutions consistent with minimum national cost, but also necessitate clear guide-lines covering the equitable allocation of responsibilities during all work phases from planning through to in-service operation.

The objective of the New Zealand Committee for the Co-ordination of Power and Telecommunication Systems is to meet these needs and, by means of publications and seminars, promote a greater awareness and understanding of the action that must be taken to ensure that Power and Telecommunication Systems coexist satisfactorily.

Membership of the Committee and its Working Parties comprised representatives for each of the following organizations:

- Transpower New Zealand Ltd.
- Telecom New Zealand Ltd.
- Electricity Engineers' Association of New Zealand Inc.
- KiwiRail
- Energy Safety Service, Ministry of Consumer Affairs

GUIDE FOR ASSESSMENT OF RISK OF EPR AND INDUCED VOLTAGE HAZARD TO TELECOMMUNICATION NETWORKS

Issue 1 Draft

Originally Prepared November 2023

ISBN

Foreword

This guide was prepared to provide criteria for assessing hazard voltage-time duration values on telecommunication networks, for both EPR and induced voltages, and provides guidelines for assessing the need for mitigation. As at February 2026, it has been provided as a draft document for information only.

NZCCPTS is indebted to the Electricity Engineers' Association of New Zealand, Telecom New Zealand Limited, and Transpower New Zealand Limited, for their contributions in the formation of this draft guide.

CONTENTS

APPENDICES

1.0 Introduction

Earth faults on HV electric power systems often involve high levels of fault current with consequent earth potential rise (EPR) in the vicinity of the fault due to the inherent ground resistance.

Voltages arising from the EPR, or induced over lengths of parallel Power and Telecommunication conductors by the high earth fault current level, can be impressed on nearby telecommunication circuits. These voltages may be hazardous to telecommunication users, personnel and equipment.

New Zealand electricity legislation (ER 58 'Electrical Interference with Telecommunication Lines, etc.') requires the hazards arising from these voltages to be addressed. One method of addressing these for induced voltages, involves complying with voltage limits copied from the 1989 ITU Directives Volume 6.

The International Telecommunications Union – Telecommunications Sector (ITU-T) (previously CCITT), a United Nations telecommunications standards organization, has since published a new Recommendation that specifies a more comprehensive set of acceptable hazard limit voltage – time durations for both induction and EPR hazard voltages, covering both human hazard and equipment damage in the one approach.

Where hazard voltage - time durations exceed the acceptable criteria in ER 58 and the new ITU-T recommendation, a risk management approach may be followed to determine the type of mitigation needed for specific cases, including installations where no mitigation may be justified because of the low probability of hazard.

This new ITU approach will enable the risk of hazard to be controlled, while enabling optimal economic mitigation solutions to be adopted, and provides an improved approach to compliance with the prime objective of Electricity Regulation 58 as set out in ER 58 (1) & (2).

2.0 Background

In the current Electricity Regulations 1997, Electricity Regulation 58 requires telecommunication installations and electrical works or installations to be constructed so that they are not likely to cause a hazard to telecommunications staff and users, or damage to telecommunications plant. Induced voltages of up to 650 volts for a duration of up to 0.5 seconds, and 430 volts for a duration of up to 5 seconds, are deemed not to be likely to cause either hazard to persons or damage to telecommunications plant.

These voltage limits are copied from the limits in Volume VI 'Danger and Disturbance' of the 1989 CCITT (now renamed ITU-T) 'Directives concerning the protection of telecommunication lines against harmful effects from electric power and electrified railway lines', which have been formally agreed between ITU, CIGRE and UIC.

The more recently published ITU-T Recommendation K.68 (02/2006) “Management of electromagnetic interference on telecommunication systems due to power systems’, specifies voltage limits higher than 650V for durations less than 0.35 seconds, but also sets voltage limits lower than 430 volts for durations over 1 second. ITU-T Rec. K.68 also provides for other voltage limit values to be applied in cases where the parties concerned follow the methodology in ITU-T Rec. K.33 to determine a case specific maximum voltage-time value.

Given the international standing of ITU-T Rec. K.68, these voltage-time limits provide an additional acceptable means of compliance with Electricity Regulation 58. Alternatively, for situations where the maximum EPR (or induced voltage) is expected to be in excess of these limits, the cost of mitigating this would be very costly, and it is expected the hazard risk is very low, a risk study may be undertaken to identify whether a ‘do nothing’ approach can be justified. These risk studies need to factor in both the risk of injury or death to humans, and the expected direct and indirect costs of damage to telecommunications plant, power plant and other property, if specific mitigation is not installed (e.g. power system fault causes insulation breakdown to telecommunications plant, which in turn causes a fire which burns a house down).

Risk studies for two of the more common general situations where the EPR is expected to be substantial (11kV phase-to-concrete pole faults, and 11kV phase-to-earth faults at rural distribution transformers) are included in Appendices A & B. These can be used as templates for other risk studies covering situations which fall outside the ER 58 and ITU-T Rec. K.68 ‘acceptable means of compliance’ limits.

3.0 Legislative Requirements

N.Z. Electricity (Safety) Regulations are primarily concerned with personnel safety. As each regulation is updated, safety outcomes are commonly being adopted instead of specific technical outcomes.

3.1 Means of Compliance

N.Z. Electricity (Safety) Regulations 2010 Regulation 33 ‘Requirements relating to construction of, or work in the vicinity of, telecommunications equipment’ states -

(1) If telecommunications equipment is being constructed in the vicinity of works or installations, the person constructing the telecommunications equipment must ensure that it is constructed so that any induced voltage or earth potential rise that is capable of being created by electricity conveyed through the works or installations and impressed onto the telecommunications equipment is not likely to cause—

(a) serious harm to any person; or

(b) significant damage to the telecommunications plant or equipment.

(2) If works or installations are being constructed in the vicinity of telecommunications equipment, the person constructing the works or installations must ensure that they are constructed so that any induced voltage or earth potential rise that is capable of being created by electricity conveyed through the works and installations and impressed onto the telecommunications equipment is not likely to cause—

(a) serious harm to any person; or

(b) significant damage to the telecommunications plant or equipment.

(3) Voltages impressed onto telecommunications equipment by induction or earth potential rise are deemed not to be likely to cause serious harm to persons if,—

(a) in respect of a fault in an AC system of supply of electricity,—

(i) the magnitude and duration of any resulting shock currents cannot exceed curve c2 of Fig 20 of IEC/TS 60479-1; or

(ii) the impressed voltages do not exceed—

(A) 430 volts AC for fault durations exceeding 0.5 seconds but not exceeding 5 seconds; and

(B) 650 volts AC for fault durations not exceeding 0.5 seconds; or

(b) in respect of a fault in a DC system of supply of electricity, or in respect of a fault on an electrified railway operating on a DC system of supply of electricity,—

(i) the magnitude and duration of any resulting shock currents cannot exceed curve c2 of Fig 22 of IEC/TS 60479-1; or

(ii) the impressed voltages do not exceed 1 000 volts peak.

(4) Voltages impressed onto telecommunications equipment by induction or earth potential rise are deemed not to be likely to cause significant damage to telecommunications equipment if, in the case of a fault in an AC system of supply of electricity, the impressed voltages do not exceed—

(a) 430 volts AC for fault durations exceeding 0.5 seconds but not exceeding 5 seconds; and

(b) 650 volts AC for fault durations not exceeding 0.5 seconds.

(5) Voltages impressed onto telecommunications equipment by induction or earth potential rise are deemed not to be likely to cause significant damage to telecommunications equipment if, in the case of a fault in a DC system of supply of electricity or a fault on an electrified railway operating on a DC

system of supply of electricity, the impressed voltages do not exceed 1 000 volts peak.

(6) A person commits an offence and is liable on conviction to a level 2 penalty if the person—

(a) constructs telecommunications equipment in the vicinity of works or installations and fails to comply with the requirements of subclause (1); or

(b) constructs works or installations in the vicinity of telecommunications equipment and fails to comply with the requirements of subclause (2).

(7) In this regulation,—

telecommunications equipment means any telecommunications line, structure, device, or thing designed or intended for use for telecommunications purposes

telecommunications line has the meaning given to it in section 2(1) of the Act.

The key requirement of ESR 33 may be summarized as:

"Any person constructing a power or telecommunications work or installation, must ensure that their construction does not cause any induced voltage, or EPR impressed onto telecommunications lines or equipment, that is likely to cause a serious harm to any person, or significant damage to telecommunications plant."

3.1.1. Compliance Approaches Currently Deemed Acceptable

ESR 33 specifies the following criteria which can be used to determine when the voltages impressed on telecommunications networks can be 'deemed' to be acceptable in terms of 3.1.

(a) Human shock currents whose magnitude and duration fall within Zones AC-1, AC-2, AC-3 or AC-4.1 of Figure 20 of IEC 60479-1 (2018), are deemed not to be likely to cause a serious harm to persons.

(b) Impressed voltages that do not exceed
   (i) 430Vrms for durations > 0.5s and ≤ 5s, or
   (ii) 650Vrms for durations ≤ 0.5s

are deemed not to be likely to cause serious harm to persons or significant damage to telecommunications plant.

The 650 V_{rms} / 430 V_{rms} induced hazard voltage limits are deemed to be an acceptable means of compliance with ER 33. They are not mandatory, and are not the only means of complying with ER 33. Situations which exceed these limits may still comply with ER 33, so long as it can be shown that they are 'not likely to cause' either serious harm to persons, or significant damage to telecommunications plant.

3.1.2 Compliance Based on ITU Recommendations

The existing applicable United Nations telecommunications sector hazard voltage limits for voltages impressed on telecommunication circuits by power networks are specified in 2008 ITU-T Directives 'concerning the protection of telecommunication lines against harmful effects from electric power and electrified railway lines', Volume 6 'Danger, damage and disturbance'. This recommendation specifies the maximum voltages on telecommunication circuits, caused by inductive coupling, capacitive coupling or conductive coupling (i.e. EPR) from electric power and electrified railway lines. [In New Zealand, responsibility for mitigation measures lies with the party wanting to install the new plant that is likely to cause a "hazardous" induction or EPR hazard situation to arise. See the NZCCPTS Cost Apportioning Guide for recommended guidelines on how the mitigation costs should be apportioned.]

These limits supersede the former induced voltage limits contained in the CCITT Directives (Vol. 6), namely 650 volts for a fault duration not exceeding 0.5 seconds, and 430 volts for a fault duration exceeding 0.5 seconds.

The voltage limits in these 2008 ITU-T Directives for preventing significant damage to telecommunications plant are:

Fault duration t [s]	Admissible Limit V_{damage} [V_{rms}]
$t \leq 0.2$	1,030
$0.2 < t \leq 0.35$	780
$0.35 < t \leq 0.5$	650
$0.5 < t \leq 1.0$	430
$1.0 < t \leq 2.0$	300
$2.0 < t \leq 3.0$	250
$3.0 < t \leq 5.0$	200
$5.0 < t \leq 10.0$	150
$10.0 < t$	60

Table 3/5 – Maximum Permissible Short Term 'Significant Damage' Voltages Induced onto Telecommunications Lines during Power Earth Faults

The voltage limits in these 2008 ITU-T Directives for preventing harmful effects to telecommunications personnel for a ‘typical situation’ are:

Fault duration t [s]	Admissible Limit $V_{danger/damage}$ [V_{rms}]
t ≤ 0.1	2,000
0.1 < t ≤ 0.2	1,500
0.2 < t ≤ 0.35	1,000
0.35 < t ≤ 0.5	650
0.5 < t ≤ 1.0	430
1.0 < t ≤ 3.0	150
3.0 < t	60

Table 3/5 – Maximum Permissible Short Term ‘Harmful Effects to Personnel’ Voltages for a ‘Typical Situation'

A ‘typical situation’ is characterised by the following aspects:

1. The work is carried out by trained and experienced personnel.
2. Only the current paths ‘hand-to-hand’ or ‘hand-to-feet’ are considered.
3. The maximum permissible current for durations ≤ 1.0s is taken from curve c2 (5% risk of fibrillation).
4. The maximum permissible current for durations 1.0s < t ≤ 2.0s is taken from curve c1 (0% risk of fibrillation).
5. The maximum permissible current for durations > 3.0 s is taken from curve b (let-go current limit = 0.5 mA for all durations).

The voltage limits in these 2008 ITU-T Directives for preventing harmful effects to telecommunications personnel for a ‘severe situation’ are:

Fault duration t [s]	Permissible Limit $V_{danger/damage}$ [V_{rms}]
t ≤ 0.06	430 (Note 1)
0.06 < t ≤ 0.1	430
0.1 < t ≤ 1.0	300
1.0 < t	60
Note 1 - The limit value is increased to 650V when current paths through the chest or hip need not be considered.	

Table 2/5 – Limit values for voltages induced onto telecommunications lines with

The effective voltage limits in these 2008 ITU-T Directives for BOTH preventing significant damage to telecommunications plant AND harmful effects to telecommunications personnel for a ‘typical situation’ become:

Fault duration t [s]	Admissible Limit $V_{danger/damage}$ [V_{rms}]
t ≤ 0.1	2,000
0.1 < t ≤ 0.2	1,500
0.2 < t ≤ 0.35	1,000
0.35 < t ≤ 0.5	650
0.5 < t ≤ 1.0	430
1.0 < t ≤ 2.0	300
2.0 < t ≤ 3.0	250
3.0 < t ≤ 5.0	200
5.0 < t ≤ 10.0	150
10.0 < t	60

Appendix B explains how these limits were derived.

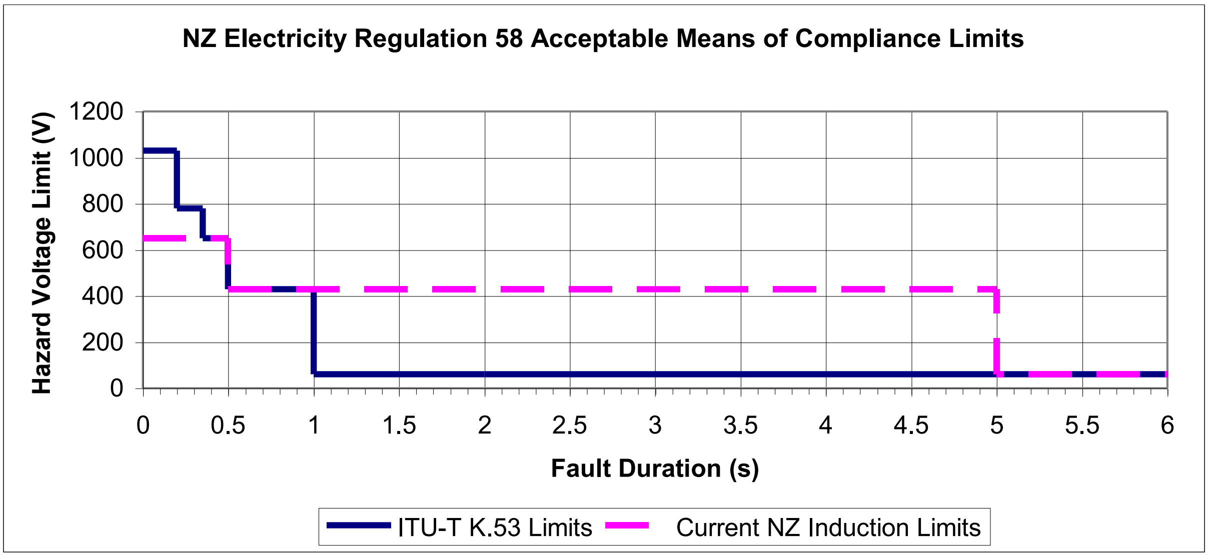

Fig. 1 Comparison of Hazard Voltage Limits

Fig. 1 compares the existing New Zealand ‘acceptable means of compliance’ voltage limits for induction (in ER 58), with the ITU recommendation K.68 hazard voltage limits.

4.0 Consideration of Voltage-Time Values Exceeding ITU Targets

The fundamental requirement of Electricity Regulations 33 is the avoidance of voltages that are ‘likely to cause’ serious harm to any person, or significant damage to a telecommunication line, structure, device, or thing. Clauses (1) to (4) of ER 33 emphasize this point.

Regulation 5 of the Electricity Regulations 2010 requires the following:

‘Works, electrical installations, fittings, electrical appliances, and associated equipment must be designed, constructed, maintained, installed and used so that they are electrically safe.’

69 (2) provides a definition for the term ‘electrically safe’ as below:

‘electrically safe’ means that there is no significant risk of injury or death to any person, or of damage to any property, as a result of the use of those works etc. or the passage of electricity through them.

The term ‘no significant risk’ is not a prescriptive quantity, however it does provide for the application of risk assessment as a means of defining electrical safety.

The basic principal being that if the level of risk is unacceptable, appropriate measures should be taken to reduce that risk. Voltages well in excess of the voltage limits in this document can be impressed on telecommunication systems during earth faults on nearby HV power networks. However if the risk of hazard and/or damage is sufficiently low, the option not to mitigate can be acceptable.

When, as a result of earth faults on nearby HV power networks, voltages in excess of ITU targets are impressed on telecommunication systems, a risk assessment may be carried out as a means of determining whether the excess voltage-time values can be acceptable in terms of Regulation 69, or alternatively determine the need for mitigation.

5.0 Experience with High-Value Low-Risk EPR Situations

NZ has a very large number of low probability EPR hazard situations where the prospective EPR is well in excess of either the Australian or the European (ITU-T Rec. K.53) hazard voltage limits. For this reason it would be prohibitively expensive to apply either of these sets of hazard voltage limits in NZ, without also having the option of carrying out a Risk Study, to determine if the EPR is likely to cause a hazard to persons, or damage to telecommunications plant.

A classic example of this sort of EPR problem in NZ can be found at rural distribution transformers, which typically have prospective EPR's in the range 3kV to 6kV. NZ generally has much higher prospective EPR voltages at its rural distribution transformers, compared to overseas countries (e.g. Europe, US, Australia, Japan), because only the NZ power system typically has the combination of:

(1) A common HV/LV earthing system at the distribution transformer. This means any EPR from a HV fault at the distribution transformer will appear (virtually in full) on the LV neutral. This conducts the distribution transformer EPR into all houses supplied by that distribution transformer. [In Australia, separate HV and LV earths are normally required unless the combined HV/LV earth resistance is less than 1Ω.]

(2) High soil resistivity, resulting in relatively high rural distribution transformer HV/LV earthing system resistances (typically 10Ω to 300Ω).

(3) A solidly earthed neutral on the zone substation 11kV supply transformers. Virtually all of Europe has isolated or impedance earthed neutrals (e.g. NER's, reactors, Petersen Coils, Arc Suppression Coils). Australia, NZ, USA and about 50% of the UK distribution voltage power systems are solidly earthed.

(4) No HV neutral. In the US, the use of a HV neutral in the distribution system means that, while distribution voltage power systems are solidly earthed and their distribution transformers have a common HV/LV earthing system, their distribution transformer fault EPR's are usually greatly reduced compared with the equivalent NZ situation.

Despite most NZ rural houses having always had prospective EPR's in the range 3kV to 6kV, there have been no known fatalities in NZ from this prospective hazard. There have, however, been some injuries caused by this prospective hazard, as well as a number of cases of damage to mains-powered customer's telecommunications equipment (in some cases causing a fire in the building), and consequential damage to the telecommunications network.

The problem presented by these high prospective EPR levels in rural NZ is mitigated to some degree by:

- very low lightning incidence, reducing the probability of power faults which could cause this EPR, and
- relatively sparse rural population density.

6.0 Determination of Prospective EPR & Induced Voltages

Guidelines for determining the prospective EPR voltages which may be impressed on telecommunication systems, when a HV power network earth fault occurs nearby, are set out in:

AS/NZS 3835.1:2006 EPR Code of Practice
AS/NZS 3835.1:2006 EPR Application Guide
AS/NZS HB 219:2006 EPR Worked Examples
EEA Guide to Power System Earthing Practice
NZCCPTS EPR Supplementary Guide??

Guidelines for determining the corresponding voltages that may be induced onto telecommunication cables, are set out in the Australian standards:

AS HB 101:1997 Induced Voltages Code of Practice
AS HB 102:1997 Induced Voltages Application Guide

These guidelines should enable voltage-time values for EPR and induced voltages to be determined, which should then be checked against the ITU permissible voltages set out in Table 1.

Voltage-time durations over the permissible values should be subject to a risk assessment as set out in the process detailed in section 7.0.

7.0 Risk Assessment Process

A process for the assessment of risk has been developed in the EEA Guide to Risk Based Earthing System Design.

The key components of the process (as presented in the EEA guide) are:

1. Determine all earth fault current paths and calculate associated fault currents.

2. Determine the hazard regions.
3. Establish the Earth-fault Frequency Factor, F_f.
4. Identify all consequences (human/animal injury or death, damage to plant). Calculate the Exposure Factor, E_f.
5. Incorporate the Group Factor, G_f.
6. Calculate the Equivalent Probability, P_e.
7. Assess the Risk Level using ALARP (As Low As Reasonably Practicable) principle. Consider the effect of uncertainty on calculated values.
8. Carry out a Cost Benefit Analysis, if required.
9. Identify and implement appropriate mitigation measures, if required.
10. Calculate residual risk following mitigation.

Table B1 below shows the relationship between the frequency of occurrence of an event and the severity of the consequence should that event arise. As the frequency of an event reduces, the risk also reduces. However the acceptability of that risk is dependent on the severity of the consequence.

The yellow band within Table B1 shows the ALARP (As-Low-As-Reasonably-Practicable) region. This is a threshold between intolerable risks and acceptable risks, where it is deemed necessary to lower risks within this band to as low as is reasonably practicable.

		Severity of Consequence				
Equivalent Probability (see Section 4)		Individual Public Death	Individual Worker Death	Electric Shock to a person	Damage / Costs	
					Severe	Minor
Frequent	>1	H	H	H	H	H
Probable	$1 – 10^{-1}$	H	H	H	H	I
Occasional	10^{-1} - 10^{-2}	H	H	I	I	L
Very unlikely	10^{-2} - 10^{-4}	H	I	L	L	N
Remote	10^{-4} - 10^{-6}	I	I	N	N	N
Improbable	10^{-6} - 10^{-7}	L	L	N	N	N
Incredible	$<10^{-7}$	N	N	N	N	N

Table B1 Risk Management Matrix

Action appropriate to the risk categories used in table B1 are shown in table B2 below.

Risk level	Description	Risk Management Region	Action
H	High	Intolerable	Must prevent occurrence regardless of costs.
I	Intermediate	ALARP	Must minimise occurrence if reasonably practical and costs are not grossly disproportionate to safety gained
L	Low		Minimize occurrence if reasonably practical and cost effective.
N	Negligible	Acceptable	Reduce occurrence further only if practical and low cost.

Table B2 Risk Level

Calculating Risk
For a risk event to arise, a person, livestock or item of equipment must be in the hazard region at the time of the fault. The probability can be calculated as:

P [hazard arises] * P [person, livestock or equipment is in hazard zone at time of earth fault]

However, since society tends to react much more adversely to the death or injury of a group of more than 3 people in one event, than it does to the death or injury of the same number of people in a number of unrelated events, an extra group factor has been added to calculate the Equivalent Probability, P_e.

$P_e = F_f * E_f * N$

where:

F_f = Earth-fault Frequency Factor
E_f = Exposure Factor
N = Equivalent number of persons in group = $G_f * n$
n = Number of persons in group
G_f = Group Factor = $(n - 1)$ for $n \geq 4$; and 1 for $n \leq 3$

Appendices 1 and 2 set out EPR risk studies for situations where telecommunication circuits are located near concrete poles or rural distribution transformers, as examples which may be useful for guidance in developing specific case studies.

8.0 Summary

New Zealand experience indicates a number of situations where the prospective hazard voltage - time duration values may not be covered by the criteria established by the original CCITT recommendation, which currently forms part of ER 58. As a result, some installations may have been provided with an excessive level of protection, and some with none at all. A proper risk evaluation may confirm many of these existing installations to be appropriately, or unnecessarily, protected.

The ITU K.68 hazard voltage limits will be less onerous than the existing NZ limits for all earth fault durations less than 1.0 second, and it is expected that that the reduction in the 430 V_{rms} hazard voltage limit to 150 V_{rms} (for $1.0 \text{ s} < t \leq 3.0 \text{ s}$) and 60 V_{rms} (for $t > 3.0$ s) will require mitigation in very few situations.

Evaluation of hazard voltage levels and the determination of appropriate mitigation using the criteria set out in this guide, is considered a significant improvement over the past approach. Overall, optimal economic solutions are expected which will be of benefit to both power system and telecommunication network owners.

9.0 References

APPENDIX A Case Study of Touch and Step Voltage Risk Analysis for Power HV Network Fault on a Concrete Pole located beside a Bus Stop

This case study is copied direct from Appendix B1 in the EEA Guide to Power System Earthing Practice – June 2009, with the kind permission of the EEA.

This case study involves an existing 11 kV transformer mounted on a concrete pole located at a bus stop. For the purposes of this case study, transferred EPR issues have been ignored.

This pole was identified as possibly carrying an EPR risk for people using the bus stop. The bus stop is typically used by people travelling to work and it can therefore be assumed that footwear is worn around the pole.

People would typically be standing on a concrete footpath when touching the pole.

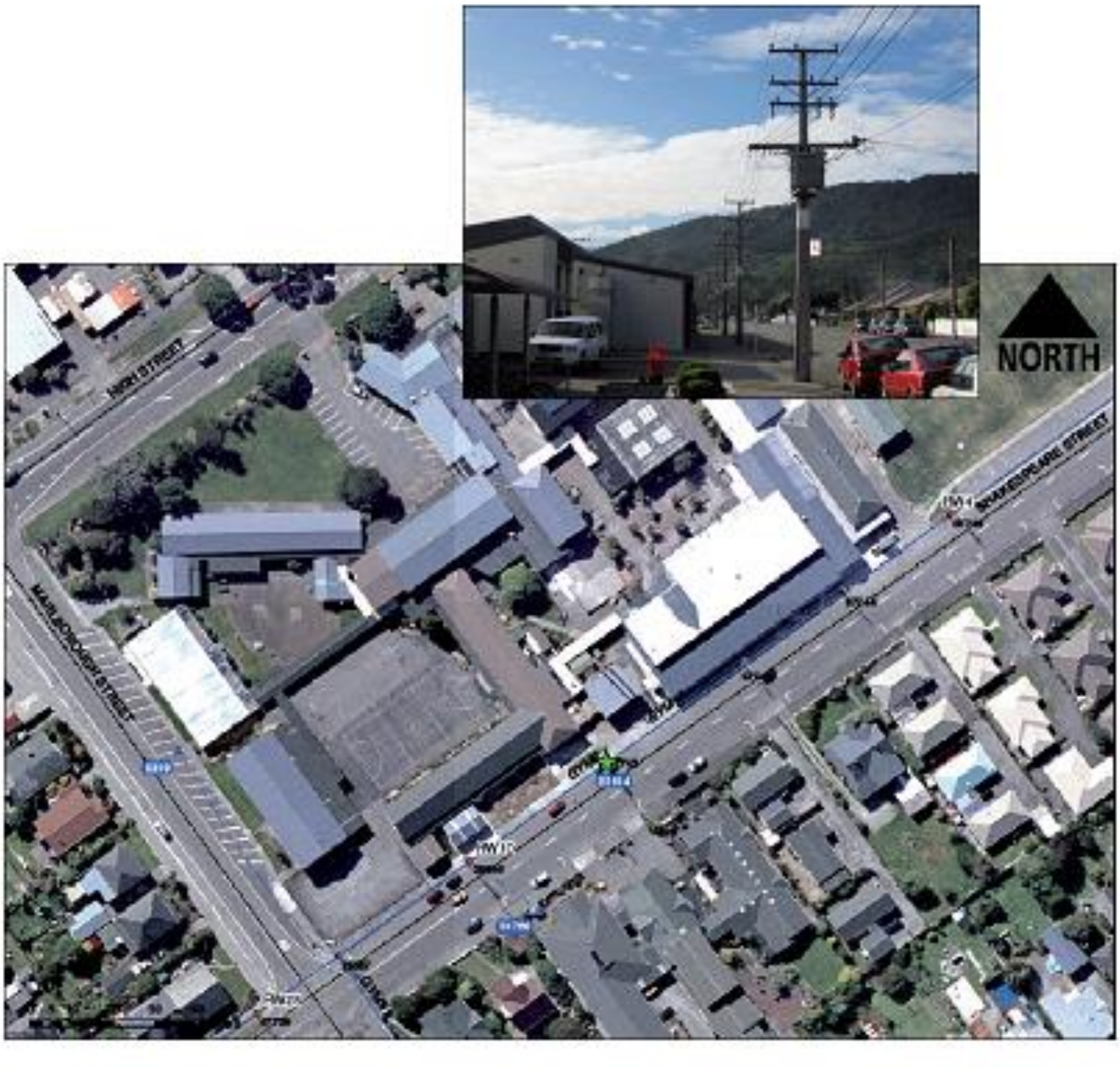

Fig. A1 Location of pole mounted transformer

This case study follows the risk management process detailed in the EEA Guide to Power System Earthing Practice – June 2009.

Step 1 Basic data

- The prospective earth fault current at the source substation is 7 kA.
- The resistance to earth of the 11 kV transformer (including the associated MEN system) was estimated as 5 Ω.
- The resistivity of wet concrete is assumed to be 50 Ω-m.
- The earth fault clearing time is 0.5 s.
- The earth fault frequency for the line is 5 per year.
- The line consists of 200 poles and does not have an overhead earth wire.
- The 11 kV transformer is connected to a small MEN system,and connection to other nearby MEN systems is not practical.

Step 2 Functional requirement

The pole meets the functional requirements.

- All exposed metalwork is bonded
- The prospective earth fault current is more than twice the feeder pickup setting to ensure the protection will operate.
- No nearby telecommunication asset.

Step 3 Pole EPR

Using parameters associated with the earth fault current path for an earth fault at the pole, the EPR on the pole was calculated as approximately 4 kV.

The parameters are:

- 2.5 km Dog ACSR between site and source substation
- 7 kA earth fault level at source substation
- 2 Ω source substation earth grid resistance
- 5 Ω site grid resistance

Step 4 Prospective tolerable step and touch voltage limits

The touch voltage limit was determined from Figure 9 in the EEA Guide to Power System Earthing Practice – June 2009, for a fault clearing time of 0.5 s and for a wet concrete resistivity of 50 Ω-m (footwear included).

The step voltage limit was determined from Figure 10 in the EEA Guide to Power System Earthing Practice – June 2009, for a fault clearing time of 0.5 s and for a soil resistivity of 50 Ω-m (footwear excluded).

V_T (limit) = 410 V
V_S (limit) = 2,150 V

Step 5 Is EPR ≤ V_T (limit) and V_S (limit)?

The EPR on the pole is greater than the step and touch voltage limits.

EPR = 4,000 V > V_T (limit) = 410 V
and V_S (limit) = 2,150 V

Step 6 Calculate actual step and touch voltages

For this case study, the actual step and touch voltages were calculated using modelling software.

A plot of touch voltages on the pole is shown below. The plot shows that the maximum touch voltage on the pole is calculated to be 2,023 V.

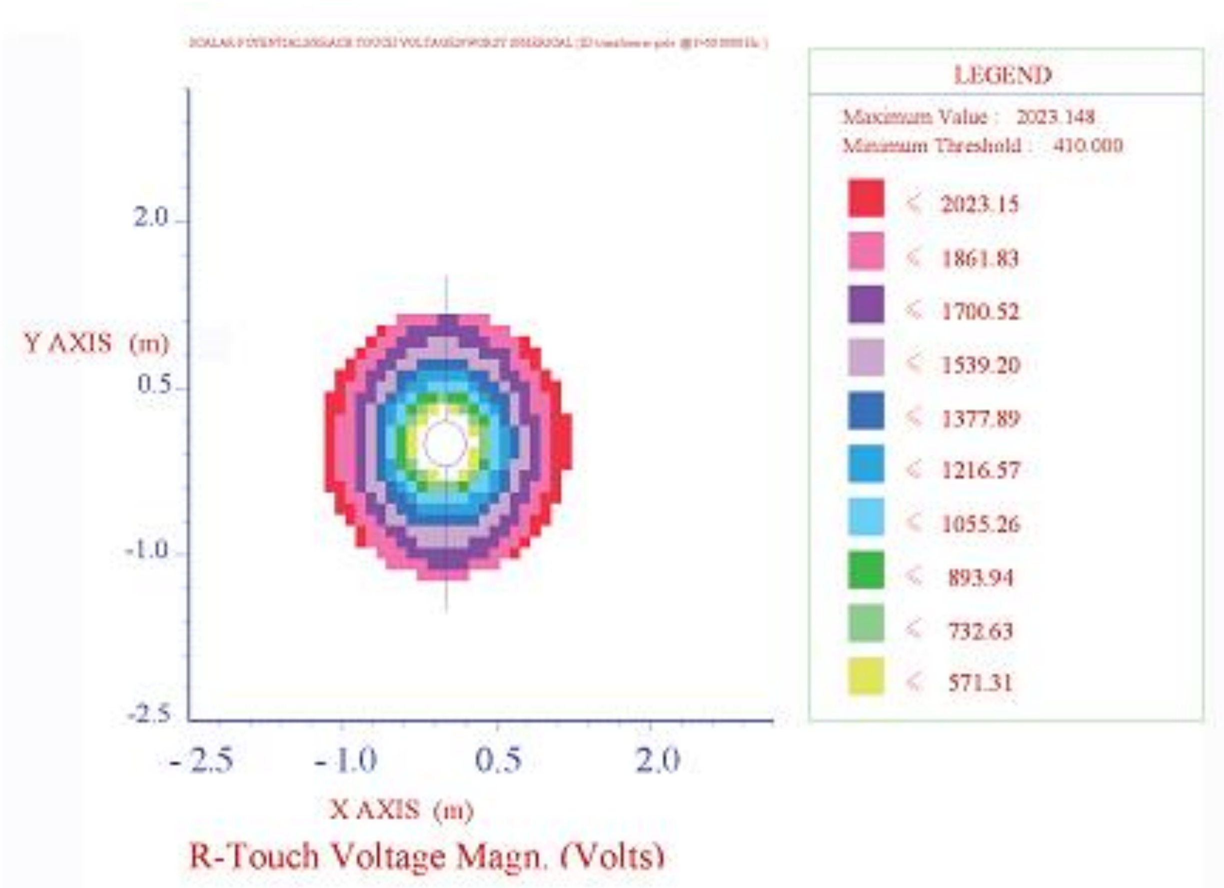

Fig. A2 Touch voltages on the pole

A plot of step voltages around the pole is shown below. The plot shows that the maximum step voltage around the pole is calculated to be approximately 1,900 V.

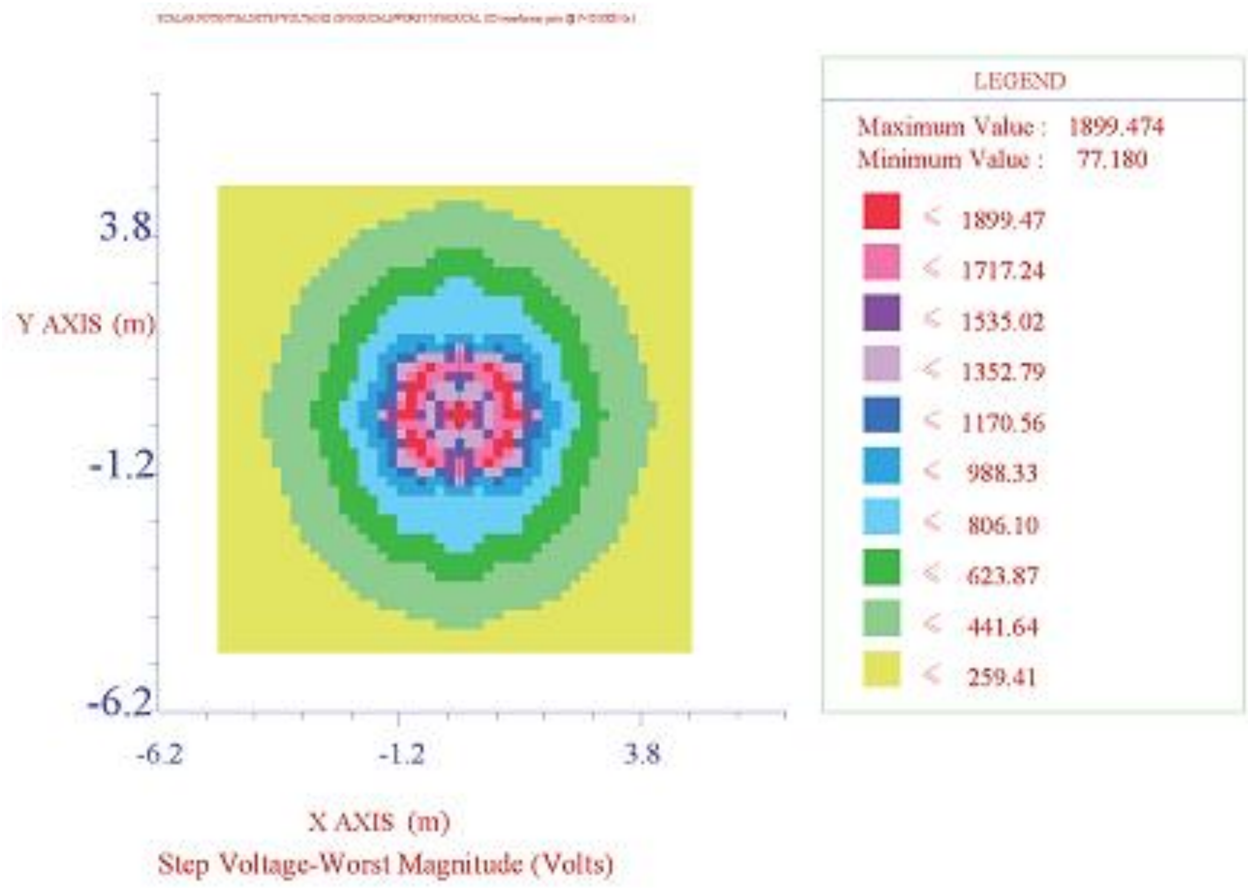

Fig. A3 Step voltages around the pole

Step 7 Are actual touch and step voltages ≤ V_T (limit) and V_S (limit)?

Actual touch voltage exceeds the touch voltage limit but the actual step voltage is less than the step voltage limit. Therefore, only touch voltage hazards exist.

Step 8 Risk assessment

The risk assessment consists of:

a) Identify the risk by identifying all hazards and extent of hazard zones.
b) This is achieved by comparing voltage limits with calculated or measured voltages.
c) Estimate people exposure to the hazards. Carry out sensitivity analysis where required

The only hazardous components at the pole are the touch voltages onto the concrete pole. The risk can be assessed by calculating the coincidence probability, P_c.

$$P_c = E_F F_F$$

Where:

$$E_F = \frac{\text{Total duration of exposure per year (in hours)}}{\text{Number of hours in a year}}$$

F_F = Average number of hazardous EPR events per year on a pole

The frequency of earth faults for the line with 200 poles is 5 faults per year. Therefore:

$$F_F = \frac{5}{200} = 0.025$$

If, for the purpose of this case study, we assume that the pole is being touched once a day for 5 minutes (i.e. someone leaning against the pole) for five days of the week (i.e. λ_E = 260 days per year), the total duration of exposure per year will be:

$$L_E = 5 \text{ minutes} \times 60 \text{ seconds} = 300 \text{ seconds}$$

Total duration of exposure = 5 minutes per day × 260 days per year

$$\text{Total duration of exposure per year (in hours)} = \frac{5 \text{ minutes a day} \times 260 \text{ days per year}}{60 \text{ minutes per hour}}$$
$$= 21.7 \text{ hours per year}$$

As there are 8760 hours in a year, the exposure factor will be:

$$E_F = \frac{21.7}{8760} = 2.5 \times 10^{-3}$$

The coincidence probability is therefore:

$P_c = 2.5 \times 10^{-2} \times 2.5 \times 10^{-3} = 6 \times 10^{-5}$

Since only one person is typically affected, N = 1 and the equivalent probability is:

$$P_e = NP_c = P_c = 6 \times 10^{-5}$$

The risk is therefore 'Intermediate' and should be minimised unless the risk reduction is impractical and the costs are grossly disproportionate to safety gained. A cost benefit analysis should be carried out to determine whether the costs of risk treatment options are disproportionate to the safety gained.

Calculate the present value (PV) of the liability:

VoSL = $10,000,000

Liability per year = 10,000,000 x 6 x 10^{-5} = $600

PV = $13,000 (assuming an asset lifespan of 50 years and a discount rate of 4%)

Step 9 Risk treatment options

A number of risk treatment options can be considered. Examples of risk treatment options are:

- Installing an underslung earth wire on the line.
- Installing a gradient control conductor and an asphalt layer around the pole.
- Installing an insulating barrier around the pole to prevent people from touching the pole.
- Replace the concrete pole with a wood pole.
- Moving the pole.
- Moving the bus stop.

A few of the above risk treatment options are detailed below to illustrate the principles.

Installing an underslung earth wire on the line.

A study has shown that an underslung earth wire would reduce the EPR on the pole to 600 V. The resulting touch voltage on the pole would then reduce to approximately 300 V which is below the tolerable touch voltage limit. The cost of this risk treatment option has been determined to be approximately $100k. Comparing the cost of risk treatment to the prevent value of the liability indicates that the cost of this risk treatment option is grossly disproportionate to the safety gained.

Installing a gradient control conductor and an asphalt layer around the pole.

With a gradient control conductor installed at a distance of one metre around the pole, the touch voltage reduces to 900 V. This touch voltage exceeds the touch voltage limit. However, if asphalt is also installed around the pole, the touch voltage limit increases to 2,000 V with the result that the touch voltage is lower than the limit. The cost of this risk treatment option is $5,000 and is below the present value of the liability. There may be some additional ongoing costs associated with maintenance of the asphalt.

Installing an insulating barrier around the pole to prevent people from touching the pole.

An insulating barrier could be installed around the pole to prevent people from being able to touch the pole. Such an insulating barrier could take the form of a wooden enclosure or a fibreglass jacket. The cost of this risk treatment option is $2,000 and is significantly below the present value of the liability. There may be some additional ongoing costs associated with maintenance of the insulating barrier.

Replacement of the concrete pole with a wood pole

By replacing the concrete pole with a wood pole, touch voltage hazards on the pole can be eliminated. If the transformer earthing conductor is insulated from touch, touch voltage hazards associated with the transformer band pole can be completely eliminated. The cost of this risk treatment option is $3,500, which is significantly below the present value of this liability

Additional risk treatment options may be considered as required.

Clearly, economically viable risk treatment options exist for this case and one of the options should be implemented. The cheapest risk treatment option may not be the best option. Other considerations may dictate which risk treatment option is selected. For example, an underslung earth wire may be the best option if a number of EPR issues exist along the line. Other mitigation options such as the use of Neutral Earthing Resistors (NERs) or Petersen Coils (Ground Fault Neutralisers) may also be considered where additional EPR issues are expected along the line.

The exposure corresponding to the transition from low to intermediate and from intermediate to high may also be calculated as a sensitivity/sanity check. The calculations below show that the exposure would have to be in excess of 40 minutes per week on average for the risk to become high. In this case, it is unlikely that someone would be exposed for so long every week.

$$\begin{aligned}\text{Maximum exposure for intermediate risk} &= 8760\frac{1\times10^{-4}}{2.5\times10^{-2}}\\ &= 35.04 \text{ hours per year}\\ &= 2{,}425 \text{ seconds per week (40 minutes per week)}\end{aligned}$$

For the risk to fall within the low risk category, the exposure for a person would need to be less than 24 seconds per week as shown below. In this case, it appears that the exposure is likely to exceed 24 seconds per week.

$$\begin{aligned}\text{Maximum exposure for low risk} &= 8760\frac{1\times10^{-6}}{2.5\times10^{-2}}\\ &= 21 \text{ minutes per year}\\ &= 24 \text{ seconds per week}\end{aligned}$$

The above sensitivity check confirms that an intermediate risk level may be adopted for this case.

The costs and practicality of the selected risk treatment option may be such that there is some residual risk after treatment is applied. This residual risk may be low and therefore acceptable. Alternatively, the residual risk may be in the intermediate category and would require further cost benefit analysis. The cost benefit analysis may be applied using the amount by which the probability of fatality has been reduced to determine whether further risk treatment is required.

APPENDIX B Derivation of ITU-T Rec. K.68 Limits

Two issues were considered, human safety and telecommunication network plant damage.

A "typical situation" is characterised by:

(i) the work is carried out by trained and experienced telecommunications personnel, and

(ii) only the human body current paths hand-to-hand and hand-to-feet need be considered.

Human Safety

The K.68 human safety limits for a "typical situation" are given below in Table A1.

Fault duration t [s]	Admissible Limit V_{danger} [V_{rms}]
t ≤ 0.1	2,000
0.1 < t ≤ 0.2	1,500
0.2 < t ≤ 0.35	1,000
0.35 < t ≤ 0.5	650
0.5 < t ≤ 1.0	430
1.0 < t ≤ 3.0	150
3.0 < t	60

Table B1 Limits related to danger in case of electromagnetic interference produced by a.c. power plants in fault condition: Typical situations (ITU-T Rec. K.68 Table 19)

Notes

1. ITU-T K.68 also specifies a danger voltage limit of 60 Vrms for electromagnetic interference produced by a.c. power plants in normal operating conditions.
2. These human safety limits were calculated using the methodology in ITU-T Rec. K.33 and K.53. ITU-T Rec. K.33 "Limits for People Safety Related to Coupling into Telecommunications System from A.C. Electric Power and A.C. Electrified Railway Installations in Fault Conditions" outlines a methodology for calculating hazard voltage limits, based on the comprehensive data from IEC 60479-1:1994, "Effects of Current on Human Beings and Livestock". [This IEC standard is recognised in the NZ Electricity Regulations.]

Telecommunications Network Plant Damage

Table A2 below shows the telecommunication network plant damage voltage limits for different fault durations. These are based on having the same energy dissipation in components connected to the telecommunication line (i.e. the same V^2t product), as for 650 V_{rms} for 0.5s. [Previous history in Europe has shown the heating impact of up to 650 V_{rms} for up to 0.5s on copper telecommunications cable conductors, and telecommunications equipment connected to these conductors, has generally not been a problem.]

Fault duration t [s]	Admissible Limit V_{damage} [V_{rms}]
$t \leq 0.2$	1,030
$0.2 < t \leq 0.35$	780
$0.35 < t \leq 0.5$	650
$0.5 < t \leq 1.0$	430
$1.0 < t \leq 2.0$	300
$2.0 < t \leq 3.0$	250
$3.0 < t \leq 5.0$	200
$5.0 < t \leq 10.0$	150
$10.0 < t$	60

Table B2 Minimum resistibility level of the equipment connected to telecommunication plants as a function of the fault duration in a.c. power plants (ITU-T Rec. K.68 Table 20)

Notes

1. Notwithstanding the above table, K.68 gives the following minimum insulation withstand voltages for the following telecommunications cable types:

Symmetric cables with paper insulated conductors	1,000 V_{rms}
Coax cables	2,000 V_{rms}
Optical fibre cables containing metallic parts (e.g. steel strength member, and/or copper pairs)	2,000 V_{rms}

Combined ‘Danger/Damage’ Hazard Voltage Limits for ‘Typical Situations’

The ITU-T Rec. K.68 combined 'danger/damage’ limits for a “typical situation”, shown in Table A3 below and in Table 1 in the main text, are simply the lesser of the human safety limit (V_{danger} from Table A1) or the plant damage limit (V_{damage} from Table A2) for each fault duration (with the fault duration category “t ≤ 0.1s” dropped).

Fault duration t [s]	Admissible Limit $V_{danger/damage}$ [V_{rms}]
$t \leq 0.2$	1,030
$0.2 < t \leq 0.35$	780
$0.35 < t \leq 0.5$	650
$0.5 < t \leq 1.0$	430
$1.0 < t \leq 3.0$	150
$3.0 < t$	60

Table B3 ITU-T Rec. K.68 Maximum Permissible Voltages for a “Typical Situation”

Combined ‘Danger/Damage’ Hazard Voltage Limits for ‘Severe Situations’

For situations where one of the aspects characterising a “typical situation” does NOT apply, e.g.

- humans other than trained and experienced telecommunications personnel may be exposed, OR
- human body current paths other than hand-to-hand or hand-to-feet need to be considered (e.g. hand-to-chest, hand-to-hip, hand-to-seat),

ITU-T Rec. K.53: 2000, ‘Values of Induced Voltages on Telecommunication Installations to Establish Telecom and A.C. Power and Railway Operators Responsibilities’ recommends applying the following “severe situation” limits:

Fault duration t [s]	Admissible Limit $V_{damage/danger}$ [V_{rms}]
$t \leq 0.1$	430
$0.1 < t \leq 1.0$	300
$1.0 < t$	(Note 1)

Table B4 Itu-T Rec. K.53 Maximum Permissible Voltages for a Severe Situation

Notes

1. Any voltage duration in excess of 1 second is considered long term by ITU-T Rec. K.33 and K.53, and attracts the ITU-T “continuous” hazard voltage limit of 60 V_{rms}.