Direct Lightning Strike Surge Propagation in Customer Premises Wiring

Presented by Mick Maytum

Prepared by Mick MAYTUM, ITU-T SG5 Q2 Rapporteur, ICT Consultant &
Tatjana GAZIVODA-NIKOLIC, Associate Q2 rapporteur, Bourns, Inc.

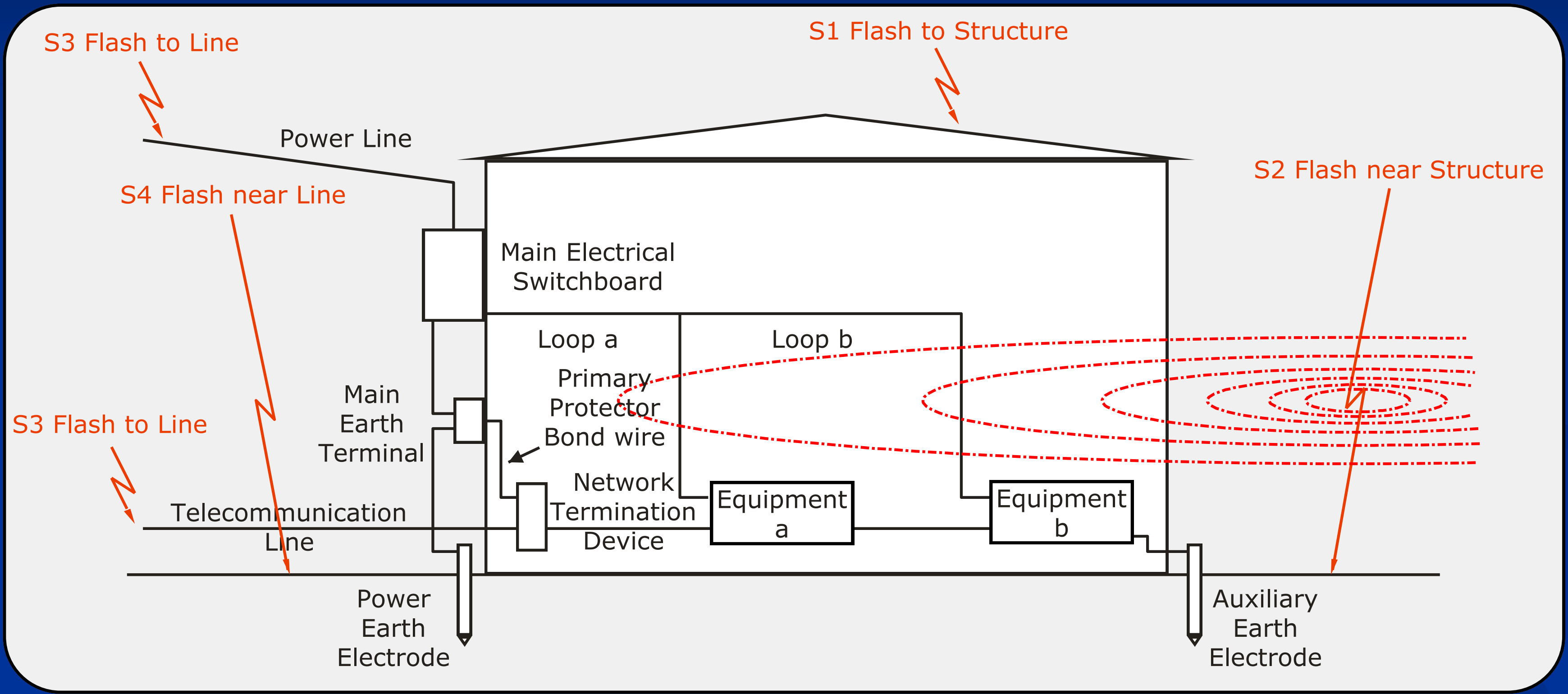
Direct Lightning Strike Surge Propagation in Customer Premises Wiring

This presentation analyses the contents of ITU-T K.98: Overvoltage protection guide for telecommunications equipment installed in customer premises. K.98 has over 160 pages and over 30 customer premise wiring voltage and current plots for the first 100 µs or more of the surge. A simulated lightning strike of 5/75 is used based on the findings of CIGRÉ TB 549 (2013) Lightning Parameters for Engineering Applications (covered at PEG 2014). The lightning strike is assumed to be either to the telecommunications line or the a.c. mains supply. This international document considers mains configuration types of TN-S, TN-C, TN-C-S, TT and IT. Only the TN-C (UK/DE/US) and TT (UK/DE/JP) configurations will be covered in this presentation. The effects of various earthing system lead lengths and earth electrode resistances are also analysed. The information in K.98 can be used to identify the most at risk customer premise situations for direct lightning damage.

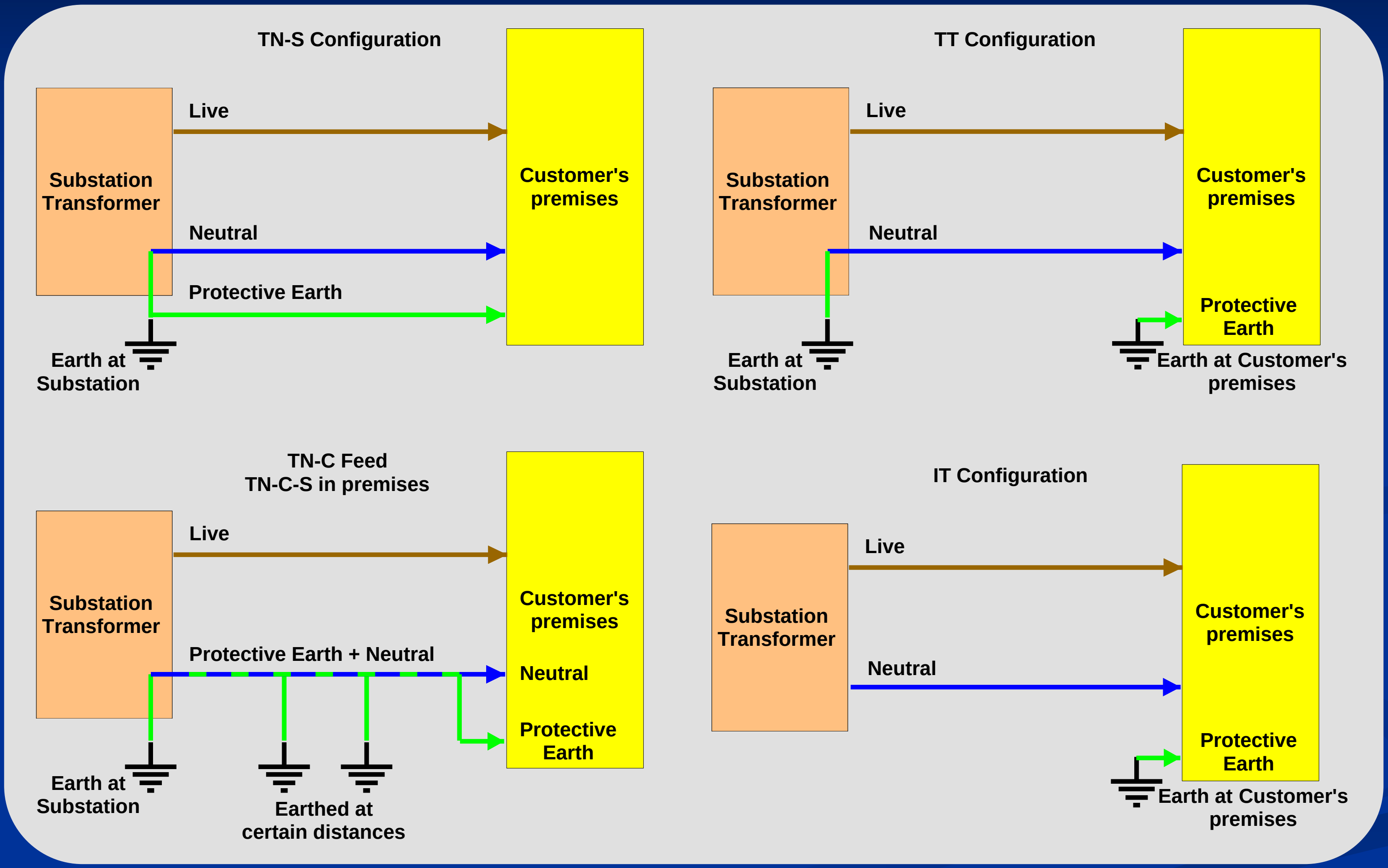
Presentation Structure

- Lightning Flash Coupling types
- Low-voltage AC mains configurations considered
- Lightning surge generators used for simulation
- simulation voltage limiting devices and equipment resistibility voltages
- Example circuit simulation and waveforms
- Four tables of simulation results
- Ethernet port voltage levels
- K.98 outcomes and recommendations
- Acknowledgement

Lightning Flash Coupling (per IEC 62305-2)



Low-voltage AC mains (IEC 60364) configurations



Lightning surge generators

The PEG 2014 presentation on “CIGRÉ (Council on Large Electric Systems) Technical Bulletin (TB) 549 (2013) Lightning Parameters for Engineering Applications” gave the negative lightning median first stroke values as 30 kA, 5.5/75 and 5.2 C. K.98 uses the same 5/75 current waveshape for simulating the line lightning surge.

The lightning performance of a 200 m length of 30 pair 0.64 mm MB cable was modelled assuming a 100 kV plastic cable sheath breakdown voltage and a plastic insulated conductor breakdown to other conductors in the order of 10 kV. This resulted in a surge generator circuit of a 100 kA current source with a shunt 1 Ω resistance to earth.

The power line conductors of Live/ Neutral/ Earth in parallel are surged with a 5 kA amplitude current source with a shunt 20 Ω resistance to earth.

Both generators can produce a maximum voltage of 100 kV.

Voltage limiting and equipment resistibility voltages

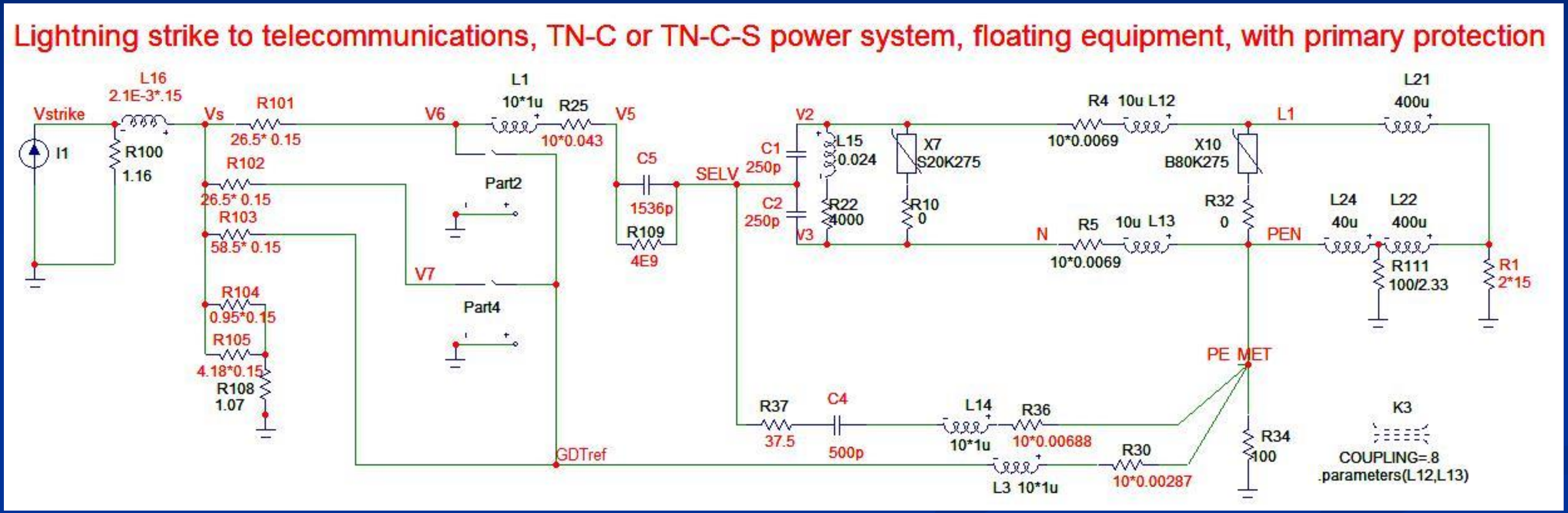
Port minimum impulse breakdown voltage

Ports	Minimum impulse voltage withstand
Class I mains transformer	2.5 kV
Class II mains transformer	5.0 kV
Floating equipment telecommunications	2.5 kV basic, 6 kV enhanced
Ethernet Port	2.5 kV impulse
Mains to telecommunications	> 5 kV for basic, > 6 kV for enhanced
Mains to Ethernet	> 5 kV for basic, > 5 kV for enhanced
Telecommunications to Ethernet	> 2.5 kV for basic, > 6 kV for enhanced

Protector limiting voltage

Voltage limiters	Limiting voltage
Telecommunications primary	600 V
SELV	100 V
Spark-gap Neutral to Protective Earth	1.5 kV
Equipment 275 V 12 kA MOV	800 V
Live to Neutral 275 V 80 kA MOV	800 V

Example Simulation Circuit



Assumes 15 subscribers connected to telecommunication cable

Simulation Circuit Component Representations

Simulation Component	Represents
R100	Resistance to earth at the lightning strike point and subsequent flashover points
L16	Inductance of telecom cable
R101	Resistance of premises working pair
R102	Resistance of premises spare pair
R103	Effective resistance of Telecom cable screen at premises
R104	Resistance of telecom cable of other 28 subscriber pairs in parallel
R105	Effective resistance of Telecom cable screen from other 14 subscribers
R108	Effective resistance of Telecom cable to earth from other 14 subscribers
Part 2	Premises working pair primary protector operating at 600 V
Part 4	Premises spare pair primary protector operating at 600 V
R25 and L1	Impedance of internal 10 metre telecom cable (Line Termination to equipment)
R203 and C5	Impedance of telecom input circuit
R22, L15, C1 and C2	Impedance of power transformer
MOV X7	Equipment inherent protection MOV
R37 and C4	Impedance of Ethernet circuit
R36 and L14	Impedance of Ethernet cable, 10 metres long
R4, R5, L12 and L13	Impedance of flat power cable, 10 metres long, coupling factor 0.8
L21 and L22	Inductance of power line back to the HV/LV transformer
L24	Inductance of protective earth conductor to other premises earth electrodes
R34	Resistance of subscriber earth electrode
R1	Resistance of LV/HV transformer earth seen by the premises

Example Results from simulation circuit

Simulation table options and results

- Mains Configuration
  - TN-C or TT
- Surge to Line
  - Mains or Telecom
- Equipment type
  - Earthed or Floating
- Telecommunication primary protection
  - Fitted or Absent
- Telecommunication primary bond wire length
  - NA, 1.5 m or 10 m
- Resistance to customer premises earth
  - 100 Ω, 100 Ω + no power outlet earth, 2 Ω or No path to earth.
- Predicted Port Damage
  - Options: None, mains, telecommunications and Ethernet

Table 1 – TN-C Simulation results, Surge to Mains Line

Equipment type	Primary protection	Telecommunication primary bond wire length	Resistance to customer premises earth	Predicted Port Damage
Earthed	No	n.a.	100 Ω	Telecommunications port.
Earthed	No	n.a.	100 Ω + no power outlet earth	Telecommunications port.
Earthed	No	n.a.	2 Ω	Telecommunications port.
Earthed	No	n.a.	No path to earth.	Telecommunications port.
Earthed	Yes	10 m	100 Ω	Telecommunications port.
Earthed	Yes	1.5 m	100 Ω	None.
Earthed	Yes	10 m	100 Ω + no power outlet earth	Telecommunications port.
Earthed	Yes	10 m	2 Ω	None.
Earthed	Yes	10 m	No path to earth.	Telecommunications port.
Floating	No	n.a.	100 Ω	Mains, telecommunications and Ethernet ports
Floating	No	n.a.	2 Ω	None.
Floating	No	n.a.	No path to earth.	Mains, telecommunications and Ethernet ports
Floating	Yes	10 m	100 Ω	None.
Floating	Yes	10 m	2 Ω	None.
Floating	Yes	10 m	No path to earth.	None.

Table 2 – TT Simulation results, Surge to Mains Line

Equipment type	Primary protection	Telecommunication primary bond wire length	Resistance to customer premises earth	Predicted Port Damage
Earthed	No	n.a.	100 Ω	Telecommunications port.
Earthed	No	n.a.	100 Ω + no power outlet earth	Telecommunications and Ethernet ports
Earthed	No	n.a.	2 Ω	Telecommunications port.
Earthed	No	n.a.	No path to earth.	Telecommunications port.
Earthed	Yes	10 m	100 Ω	Telecommunications port.
Earthed	Yes	1.5 m	100 Ω	Telecommunications port.
Earthed	Yes	10 m	100 Ω + no power outlet earth	Telecommunications port.
Earthed	Yes	10 m	2 Ω	None.
Earthed	Yes	10 m	No path to earth.	Telecommunications port.
Floating	No	n.a.	100 Ω	Mains, telecommunications and Ethernet ports
Floating	No	n.a.	2 Ω	Mains, telecommunications and Ethernet ports
Floating	No	n.a.	No path to earth.	Mains, telecommunications and Ethernet ports
Floating	Yes	10 m	100 Ω	None.
Floating	Yes	10 m	2 Ω	None.
Floating	Yes	10 m	No path to earth.	None.

Table 3 – TN-C Simulation results, Surge to Telecommunications Line

Equipment type	Primary protection	Telecommunication primary bond wire length	Resistance to customer premises earth	Predicted Port Damage
Earthed	No	n.a.	100 Ω	Telecommunications port.
Earthed	No	n.a.	100 Ω + no power outlet earth	Telecommunications port.
Earthed	No	n.a.	2 Ω	Telecommunications port.
Earthed	No	n.a.	No path to earth.	Telecommunications port.
Earthed	Yes	10 m	100 Ω	Telecommunications port..
Earthed	Yes	1.5 m	100 Ω	None.
Earthed	Yes	10 m	100 Ω + no power outlet earth	None.
Earthed	Yes	10 m	2 Ω	Telecommunications port.
Earthed	Yes	10 m	No path to earth.	Telecommunications port.
Floating	No	n.a.	100 Ω	Mains, telecommunications and Ethernet ports
Floating	No	n.a.	2 Ω	Mains, telecommunications and Ethernet ports
Floating	No	n.a.	No path to earth.	Mains, telecommunications and Ethernet ports
Floating	Yes	10 m	100 Ω	None.
Floating	Yes	10 m	2 Ω	None.
Floating	Yes	10 m	No path to earth.	None.

Table 4 – TT Simulation results, Surge to Telecommunications Line

Equipment type	Primary protection	Telecommunication primary bond wire length	Resistance to customer premises earth	Predicted Port Damage
Earthed	No	n.a.	100 Ω	Telecommunications port.
Earthed	No	n.a.	100 Ω + no power outlet earth	Telecommunications and Ethernet ports
Earthed	No	n.a.	2 Ω	Telecommunications port.
Earthed	No	n.a.	No path to earth.	Telecommunications port.
Earthed	Yes	10 m	100 Ω	Telecommunications port.
Earthed	Yes	1.5 m	100 Ω	None.
Earthed	Yes	10 m	100 Ω + no power outlet earth	Telecommunications port.
Earthed	Yes	10 m	2 Ω	Telecommunications port.
Earthed	Yes	10 m	No path to earth.	Telecommunications port.
Floating	No	n.a.	100 Ω	Mains, telecommunications and Ethernet ports
Floating	No	n.a.	2 Ω	Mains, telecommunications and Ethernet ports
Floating	No	n.a.	No path to earth.	Mains, telecommunications and Ethernet ports
Floating	Yes	10 m	100 Ω	None.
Floating	Yes	10 m	2 Ω	None.
Floating	Yes	10 m	No path to earth.	None.

Ethernet port Damage, Surge to Mains Line

Table 5 – TN-C Simulation results, Surge to Mains Line

Equipment type	Primary protection	Telecommunication primary bond wire length	Resistance to customer premises earth	Ethernet Port Voltage
Floating	No	n.a.	100 Ω	974 V, mains transformer flashover 15 kV
Floating	No	n.a.	No path to earth.	1.1 kV, mains transformer flashover 17 kV

Table 6 – TT Simulation results, Surge to Mains Line

Equipment type	Primary protection	Telecommunication primary bond wire length	Resistance to customer premises earth	Ethernet Port Voltage
Earthed	No	n.a.	100 Ω + no power outlet earth	13.7 kV
Floating	No	n.a.	100 Ω	21 kV
Floating	No	n.a.	2 Ω	21 kV
Floating	No	n.a.	No path to earth.	22 kV

Ethernet port Damage, Surge to Telecommunications Line

Table 7 – TN-C Simulation results, Surge to Telecommunications Line

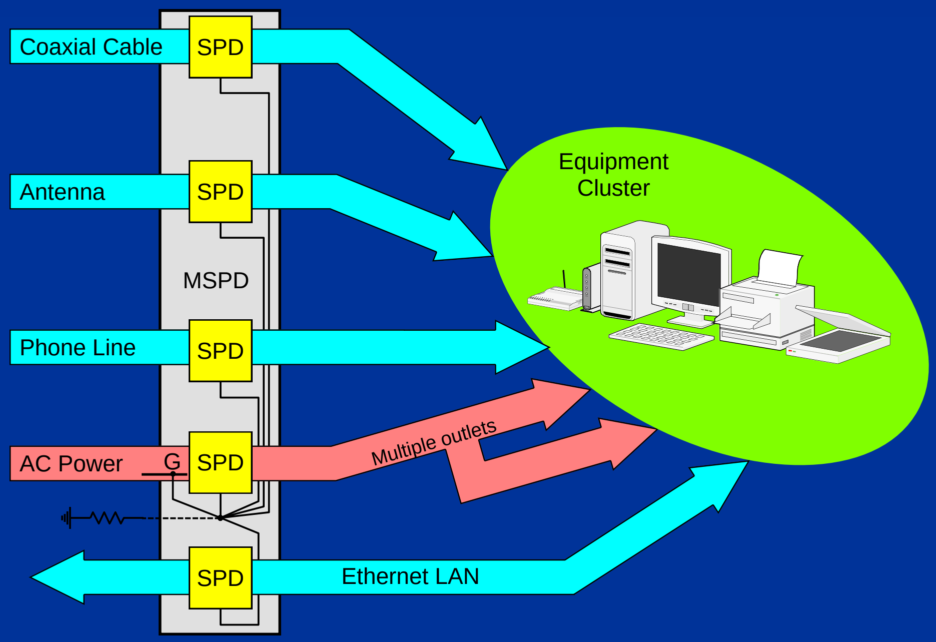
Equipment type	Primary protection	Telecommunication primary bond wire length	Resistance to customer premises earth	Ethernet Port Voltage
Floating	No	n.a.	100 Ω	2.6 kV
Floating	No	n.a.	2 Ω	5.6 kV
Floating	No	n.a.	No path to earth.	2.3 kV, mains transformer flashover 9 kV

Table 8 – TT Simulation results, Surge to Telecommunications Line

Equipment type	Primary protection	Telecommunication primary bond wire length	Resistance to customer premises earth	Ethernet Port Voltage
Earthed	No	n.a.	100 Ω + no power outlet earth	6.3 kV
Floating	No	n.a.	100 Ω	3.8 kV, mains transformer flashover
Floating	No	n.a.	2 Ω	10.5 kV, mains transformer flashover
Floating	No	n.a.	No path to earth.	5.8 kV, mains transformer flashover

K.98 outcomes and recommendations

Only certain combinations of mains supply, equipment, primary protection, primary bonding lead length and earthing resistance are predicted to survive the applied surges, see Tables 1 through 4 on previous slides.



Where damage occurs it is recommended to fit a Multi-service Surge Protective Device, MSPD, to enhance the surge resistibility of equipment or equipment clusters. MSPDs have been covered by the PEG 2008 "Multi-service Surge Protection Devices: Solving the Problems of Real-Life Equipment Installations" presentation.

Direct Lightning Strike Surge Propagation in Customer Premises Wiring

Phil Day spent over a year writing K.98 and simulating an enormous number of customer premises environments. This epic work merits close study to promote a better understanding of how lightning surges propagate in premises. He deserves our thanks for this work.

I hope this presentation has been interesting and will encourage you to obtain and study ITU-T Recommendation K.98

Mick Maytum
Email: m.j.maytum@ieee.org
Website: http://pes-spdc.org/