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ITU-T K.118 – Requirements for lightning protection of fibre to the distribution point equipment – Overview

Supplement 30 to ITU-T K-series Recommendations

ITU-T K.118 – Requirements for lightning protection of fibre to the distribution point equipment – Overview

Summary

Supplement 30 to ITU-T K-series Recommendations provides the subsequent informative references and materials that have appeared since the publication of Recommendation ITU-T K.118.

As telephone lines are constantly being repurposed for digital use, this Supplement looks at the lightning threats that repurposing for digital G.fast (fast access to subscriber terminals) may bring.

Since the publication of Recommendation ITU-T K.118, Requirements for lightning protection of fibre to the distribution point equipment, the system, often called G.fast (fast access to subscriber terminals) with reverse power feed (RPF), has had extensive deployment. This Supplement provides the subsequent informative references and materials that have appeared since the publication of Recommendation ITU-T K.118.

The conventional telephone twisted pair connecting wire, termed the link (transmission path between two cabling system interfaces, including the connections at each end), between the distribution point unit (DPU) and the customer premises equipment (CPE) usually has a maximum length of up to 300 m.

Electrical lightning stresses on the connected equipment at the link ends are considered to arise from the lightning disturbances on the CPE powering source, differential earth potential rise (EPR) of the link ends, and possibly magnetic induction to the link cable. This Supplement mainly concerns itself with the differential EPR values between the link ends.

History

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1 Scope

Telephone lines are constantly being repurposed for digital use. This Supplement looks at the lightning threats that repurposing digital G.fast (fast access to subscriber terminals) may bring.

Since the publication of [ITU-T K.118], Requirements for lightning protection of fibre to the distribution point equipment, the system, often called G.fast (fast access to subscriber terminals) with reverse power feed (RPF), has had extensive deployment. This Supplement provides the subsequent informative references and materials that have appeared since the publication of [ITU-T K.118].

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2 References

[ITU-T K.118] Recommendation ITU-T K.118 (2016), *Requirements for lightning protection of fibre to the distribution point equipment*.

3 Definitions

3.1 Terms defined elsewhere

This Supplement uses the following terms defined elsewhere:

3.1.1 balanced cable [b-ITU-T L.76]: Cable consisting of one or more metallic symmetrical cable elements (twisted pairs or quads).

3.1.2 cabling [b-ITU-T L.76]: System of telecommunications cables, cords and connecting hardware that supports the connection of information technology equipment.

3.1.3 link [b-ISO/IEC 11801-3]: Transmission path between two cabling system interfaces, including the connections at each end.

3.1.4 twisted pair [b-ISO/IEC 11801-3]: Cable element consisting of two insulated conductors twisted together in a regular fashion to form a balanced transmission line.

3.2 Terms defined in this Supplement

None.

4 Abbreviations and acronyms

This Supplement uses the following abbreviations and acronyms:

EPR Earth Potential Rise

PE Protective Earth

RPF Reverse Power Feed

SPD Surge Protective Device

5 Conventions

None.

6 Analogue and digital configurations

6.1 Plain old telephone system (POTS)

POTS has a central power source in the exchange or switch. Power from the centralised source is distributed to the connected customer premises. Typically, the nominal source voltage is −48 V with a premise prospective short circuit current of around 50 mA. Analogue voice format is used on the connecting twisted-pair wire line, which can be many km loops. The equipment at both ends of the line are referenced to the ground, either directly or via a surge protective device (SPD), see Figure 1.

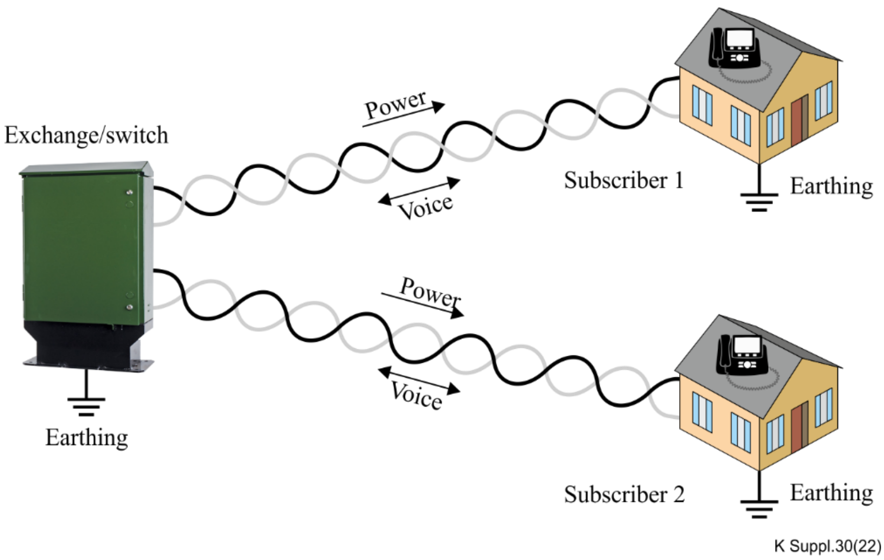

Figure 1 – Classic POTS configuration

6.2 G.fast

The term G.fast (fast access to subscriber terminals) comes from [b-ITU-T G.9700]. G.fast has a network fibre optic feed, and targets sub-km loop lengths up to 300 m with minimum speeds in the region of 200 MB/s.

A unique G.fast feature is that the subscriber provides reverse powering for their G.fast feed electronics section of the distribution point unit (DPU). In Europe, ETSI [b-ETSI TS 101 548-1] covers the various reverse powering arrangements. The basic G.fast short range 2 (SP2) loop reverse powering level is similar to the POTS powering level of DC 60 V and 15 W maximum, see Figure 2.

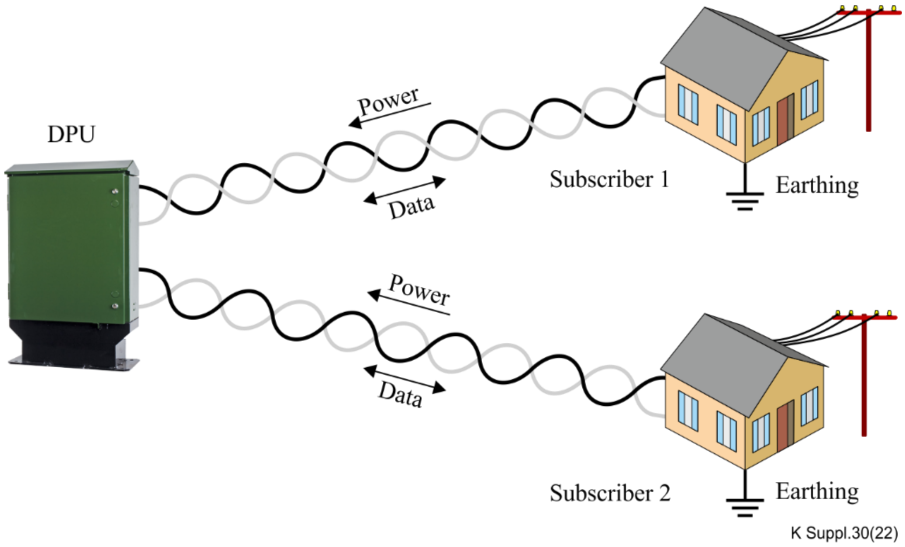

Figure 2 – G.fast – DPU and subscriber network

The DPU can be in a cabinet or a box that can be on a pole or in a manhole. The latter arrangement will often mean that the DPU will be without an earth connection and the DPU will be a common connection point for the subscribers' lines.

The G.fast equipment at both the ends of the loop contains digital processing electronics and a diplexer or duplexer to separate or merge the data and the powering. At the DPU there will be a power conversion function and at the subscribers' end a power source, which may use the AC mains.

Besides more subscribers, ETSI [b-ETSI TS 101 548-1] describe many more G.fast options such as retaining a POTS connection, and an extended reach version with the powering voltage increased up to 120 V and a slower data rate.

7 Lightning threats

7.1 Surge coupling mechanisms

[b-ITU-T K.39] states there are four main coupling mechanisms for surges to couple into networks and equipment:

- Direct coupling (permanent or transient)
- Magnetic coupling
- Electric coupling
- Electromagnetic coupling

7.1.1 Direct coupling

7.1.1.1 Direct coupling permanent

Direct coupling is when lightning strikes an object such as a radio tower or the earth. Subsequently, the lightning current finds its way to earth. Once connected to the earth, the current spreads out in the earth and this results in an earth potential rise (EPR), which decreases with distance from the strike. A detailed analysis of earth potential rise (EPR) is given in clause 10.

7.1.1.2 Direct coupling transient

The operation of equipment surge protective components (SPCs) or external surge protective devices (SPDs) can couple transients into a protected service, or service transients can be injected into the equipotential bonding network causing localised voltage rise due to bonding conductor inductance.

Voltage limiters are used to protect the insulation from breakdown and components from failing. Voltage limiting must not operate under steady-state conditions. ETSI [b-ETSI TS 101 548-1] specifies that for any applied protection the DC resistance to earth shall exceed 2 MΩ, measured at a DC test voltage of ±100 V.

7.1.2 Magnetic coupling

Transient magnetic fields will induce voltages and, in low impedance circuit loops induces currents in the cabling. Transient magnetic fields caused by lightning can be from the lightning itself or the lightning current flowing in the lightning protection system (LPS), down conductor on the side of a building. Inside the building, network cabling can run parallel and quite close to an external LPS down conductor. The down conductor mutual coupling inductance, M, to the network cabling can be several µH. Figure 3 shows an example situation where a lightning current or the current in an LPS down conductor radiates a transient magnetic field that couples with an open-circuit and a short-circuit twisted-pair loops. The lightning current is a 100 A peak, 5/75 current impulse coupled to each loop type by a mutual inductance of 5 µH. The time graph of Figure 3 shows the lightning current (green line), a short-circuit loop conductor current (blue line), and the open-circuit loop end-to-end cable voltage (red line).

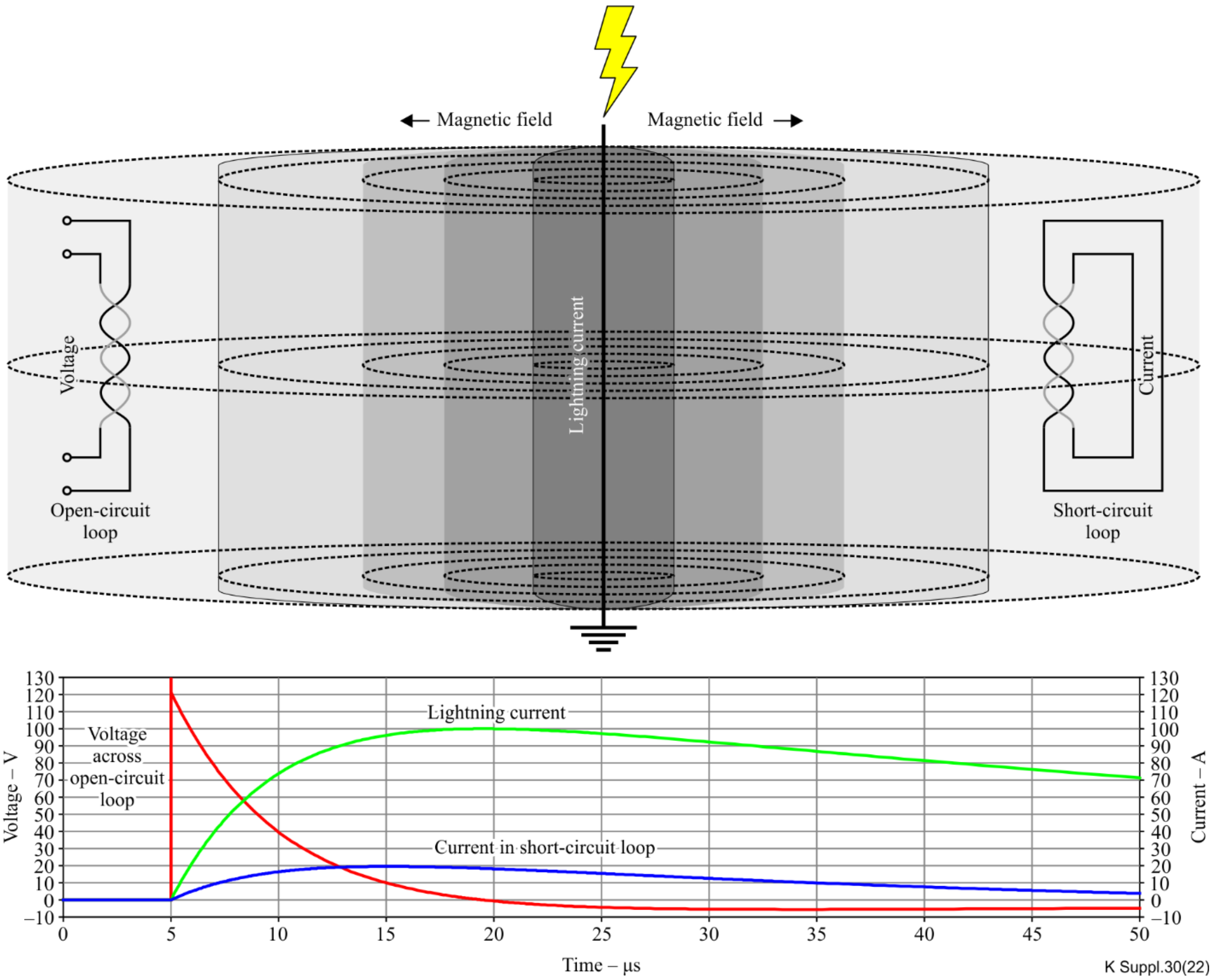

Figure 3 – Magnetically induced cable voltage and current from lightning current

In the open-circuit loop, the induced voltage will be dependent on 5 µH×(di/dt), where di/dt is the lightning rate of current change with time. The time graph green line is the lightning current, the blue line is the current in any loop and the redline is the cable end-to-end voltage. The peak voltage is

110 V indicating an initial lightning current di/dt of 110/5 = 22 A/µs. After the lightning current peaks, the decreasing current has a negative di/dt producing a cable voltage of about −5 V. Had the lightning current peak been 10 kA the peak voltage would be 11 kV. The peak cable voltage is balanced, for example, one end would be −5.5 kV and the other end would be 5.5 kV. However, if one end was connected to the earth or a surge protective device (SPD) is applied there, then the other cable end would experience nearly 12 kV as shown in Figure 4.

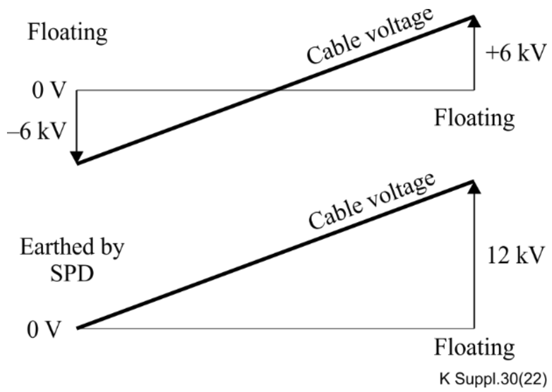

Figure 4 – Line end voltages due to magnetic coupling with and without a single SPD

In the short-circuit loops, the total circuit ampere-turns (AT), will try to oppose the lightning current magnetic field AT. The time graph green line is the lightning current, and the blue line is a short-circuit loop conductor current. The peak loop current is 46 A, but decays more rapidly than the lighting current.

7.1.3 Electric coupling

This form of coupling often occurs due to port-to-port capacitance. For example, if a power supply AC mains port to DC output port capacitance was 100 pF and the equipment that is being powered had a power port capacitance of 200 pF, then the powered equipment would be subjected to 1/3 of a rapidly rising mains transient voltage across it.

7.1.4 Electromagnetic coupling

Electromagnetic waves are the result of simultaneous propagated electric and magnetic waves (radio waves). As a result of their mutual interaction electromagnetic waves travel far greater distances than a magnetic wave or an electric wave.

Inside equipment switching type SPCs, such as gas discharge tubes (GDTs), can switch with times in the 10 ns region, which can cause the radiation of electromagnetic waves. If the equipment has poor EMC resistivity, there is a possibility of an integrated circuit latch-up.

8 Mitigation methods

Overvoltage surges are normally classified into two types; common-mode and differential-mode. Common-mode means all the service conductors have the same level of surge (equipotential). Differential-mode means that the surge voltage is developed between the service conductors. Most surges are coupled in common-mode, but insulation breakdown and SPD operation can convert a common-mode surge into a differential surge. Figure 5 shows several mitigation options for a common-mode surge:

a) voltage limits the surge voltage from a reference potential (usually earth) by using voltage limiting components;

b) blocks the voltage surge with an isolating transformer;

c) filters out the surge frequencies if the service and lightning spectrums do not overlap;

d) uses a common-mode choke, which has a high impedance to common-mode surge and a low impedance to the differential signal;

e) uses a series current limiter. Thermally operated current limiters will not normally operate under surge conditions, but electronic current limiters will operate under surge conditions.

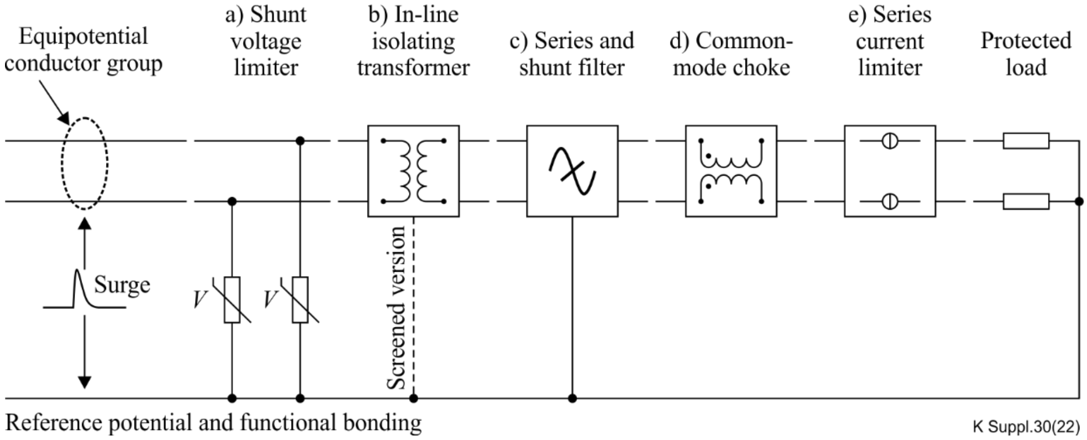

Figure 5 – Common-mode surge mitigation options

Figure 6 shows several mitigation options for a differential-mode surge.

a) voltage limits the surge voltage between the conductors by using voltage limiting components;

b) if the signal transformer core saturates, stopping the transformer action, surge truncation will occur;

c) filters out the surge frequencies if the service and lightning spectrums do not overlap;

d) uses a series current limiter. Thermally operated current limiters will not normally operate under surge conditions, but electronic current limiters will operate under surge conditions;

e) not a surge mitigation component, a differential-mode choke can be used for DC feed and extraction without shunting the signal.

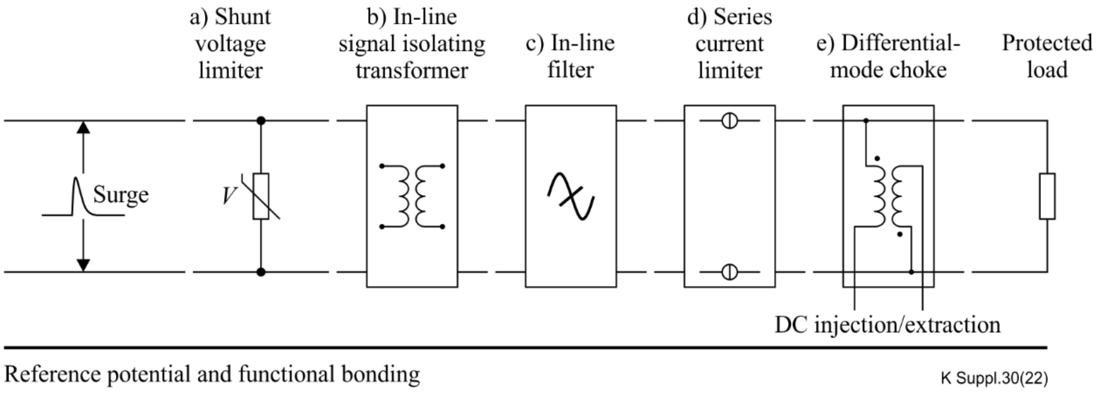

Figure 6 – Differential-mode surge mitigation options

9 Recommendation ITU-T K.118 protection parameters

[ITU-T K.118] recommends that high current carrying protectors are used separately (primary protection) or in multi-service protector devices (MSPDs), or in the DPU equipment, or in the CPE, are to have the following rated current parameters:

– Minimum of a 5 kA 8/20 rating per side (i.e., 10 kA 8/20 in the gas discharge tube (GDT) centre electrode for a 3-electrode type).

For printed circuit tracks [ITU-T K.118] recommends:

– A current carrying capacity for the equipment printed circuit tracks is 5 kA 8/20 per conductor, and 30 kA 8/20 for the conductors carrying the sum of the single conductor currents.

Should there be a possibility of a power contact to the telecommunications line causing the overvoltage protector to overheat and possibly cause a fire, the voltage limiter threshold voltage is to be above the mains voltage or use thermal protection to prevent overheating.

For floating equipment, which does not require a protective earth (PE) and is powered from a SELV, ES1, ES2 circuit or has a double insulated power supply, [ITU-T K.118] recommends:

– For DPU equipment a 20 kV of voltage withstand is a recommended

– For CPE a 6 kV of voltage withstand is a recommended

[ITU-T K.118] states that when lightning protection above the inherent resistibility level of 1.5 kV is required, there are two options:

– Add a primary protection outside the equipment when a risk assessment indicates that the protection should be installed.

– Design the equipment with integral high current carrying protection components (e.g., gas discharge tubes (GDTs)) as part of the inherent protection. Typically, this is only implemented for access network equipment.

If a local earth is used some surge current will be diverted to that earth. If there is no local earthing the lightning current from one subscriber will be passed on to other subscribers. Figure 7 shows the DPU protection arrangement. Figure 8 shows an example DPU diplexer, where the differential-mode choke mitigates the shunt loading of the data signal, and the common-mode choke mitigates the common-mode surge voltages.

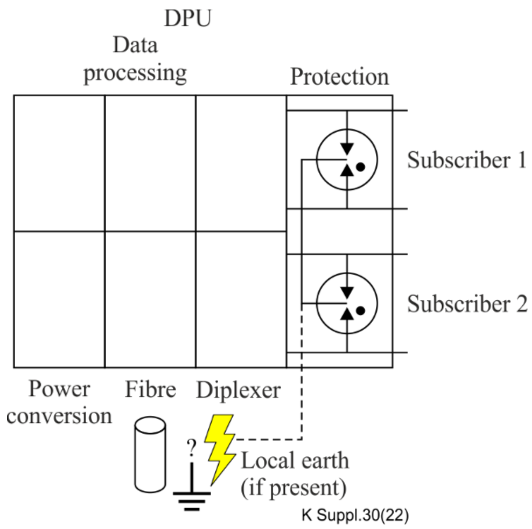

Figure 7 – DPU protection

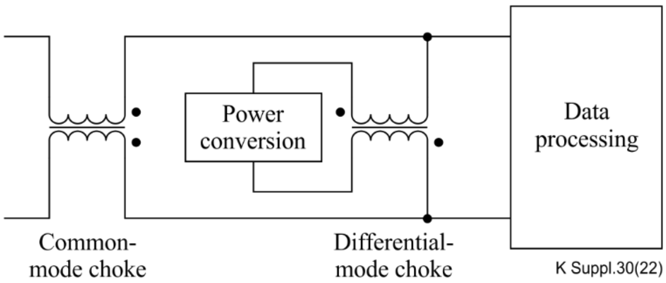

Figure 8 – Example diplexer circuit at DPU

10 G.fast network lightning threats

Taking clause 7 into account, the G.fast overvoltage threats are summarized in Figure 9.

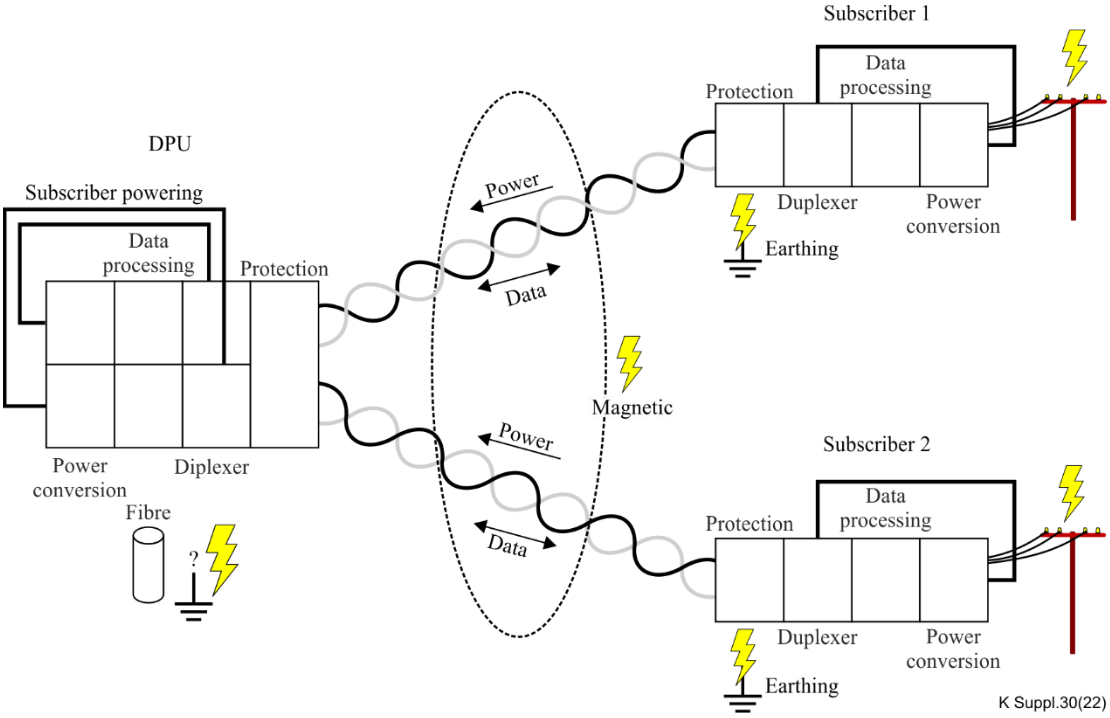

Figure 9 – Overvoltage lightning threats

A significant threat is an EPR which will now be analysed.

10.1 EPR analysis

The effects of earth potential rise (EPR) on a G.fast system are discussed in [b-Martin 2022]. This clause summarizes the paper's contents. The network analysed consists of a DPU connected to one or two subscribers.

10.2 Analysis assumptions

The lightning stroke occurs to a uniform ground of resistivity ρ of 400 Ω-m (about average, according to [b-MIL-HDBK-419A]) and at a distance of 50 m from the DPU. As the ground is uniform the equipotential voltage levels from the stroke consist of a series of rings. Eight-foot, 5/8-inch diameter ground rods at distances r_1 and r_2 will have an EPR voltage difference of $V_a – V_b$, see Figure 10. Screened cable connected between points A and B will carry a current, I_{screen}, due to the EPR difference.

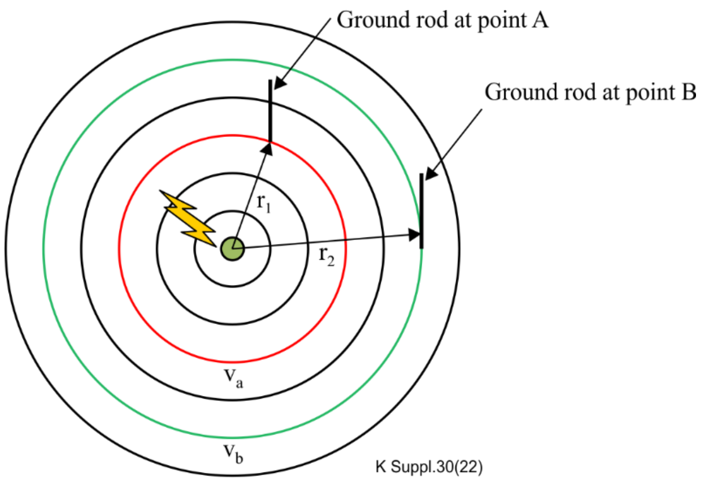

Figure 10 – Earth's potential rise from lightning stroke

10.3 Analysis results

Four cases are considered with the DPU earthed or unearthed and the connection cable is screened or unscreened. In all cases, it is assumed that there is no overvoltage protection to the ground applied. The lightning voltages and currents are normalized to the lightning stroke amplitude. Cigre [b-Cigre 549] states that the average negative first lightning current is 30 kA peak. Table 1 shows the analysis results.

Table 1 – Resultant lightning stroke currents and voltages

Case	Subscribers	DPU	Cable	Cable distance	30 m	300 m
1	1	earthed	screened	EPR difference	0.56 kV/kA	2.0 kV/kA
				I_{screen}	153 A/kA	108 A/kA
				I_{ground}	890 A/kA	964 A/kA
1	2	earthed	screened	EPR difference	0.27 kV/kA	0.89 kV/kA
				I_{screen}	68 A/kA	52 A/kA
				I_{ground}	500 A/kA	493 A/kA
2	1	earthed	unscreened	EPR difference	0.94 kV/kA	2.16 kV/kA
				I_{ground}	1 kA/kA	1 kA/kA
3	2	unearthed	screened	EPR difference	0.58 kV/kA	0.58 kV/kA
				I_{screen}	35 A/kA	35 A/kA
				I_{ground}	500 A/kA	493 A/kA
4	2	unearthed	unscreened	EPR difference	0.61 kV/kA	0.61 kV/kA
				I_{ground}	497 A/kA	497 A/kA

10.4 Discussion

Summarizing the results for the four cases discussed, based on the assumptions made, the resultant insulation voltage ranges from 17 kV to 65 kV for a single connection. The results are consistent with those reported by the study of large electrode systems [b-Pretorius]. For N connections, the breakdown voltage is the single connection case divided by N. The results were for median values of the variables and could be more or less, depending on the assumptions made and the configuration of the connections.

If there is no overvoltage protection installed at the premises or the DPU, then there are two insulation barriers that break down for failure to occur. If we assume that an acceptable failure rate requires a single insulation barrier to withstand 7 kV, then an EPR voltage difference of at least 14 kV needs to occur for failure to happen (assuming both barriers have the same capacitance).

If overvoltage protection is installed it is best to install it at both the DPU and the customer premises otherwise the unprotected equipment will see the full EPR voltage difference and would need to withstand the previously mentioned 14 kV.

If overvoltage protection is installed at both the structures and the DPU, system voltage breakdown is not likely. In this case, the issue could be that there is I^2t damage due to the EPR-driven current.

10.5 Summary

The purpose of this work was to estimate whether equipment without overvoltage protection in a multiple structure environment could fail due to insulation breakdown from EPR caused by lightning, when the multiple structures have a mutual connection, as might be the case in a suburban environment. To help answer the question, calculations were done, based on a model of structures in that environment without overvoltage protection.

The results of the calculations were that insulation breakdown could happen, depending on the values chosen for the variables in the models and the geometry of the connections. In this environment, insulation barriers at both the DPU and the premises should withstand at least 7-8 kV to provide adequate withstand voltage. A higher withstand voltage would likely be required in more extreme situations.

Finally, we discussed if system insulation breakdown would be a problem if overvoltage protection was installed at one end of the line, but not at the other end. Essentially, such an arrangement would double the unprotected equipment withstand requirement.

16 Further reading

[b-ITU-T G.9701] Recommendation ITU-T G.9701 (2019), *Fast access to subscriber terminals (G.fast) – Physical layer specification.*

[b-ISO/IEC TS 29125] ISO/IEC TS 29125:2017, *Information technology – Telecommunications cabling requirements for remote powering of terminal equipment*.

[b-Martin 2016] Martin, A. R. (2016), *Effects of Lightning on ICT Circuit – Induction and GPR/GCR 2016 ATIS Protection Engineers Group (PEG): Electrical Protection of Communications Networks Conference.*

[b-Pretorius-1] Pretorius, P. H. (2018), *Loss of equipotential during lightning ground potential rise on large earthing systems*, 2018 IEEE International Symposium on Electromagnetic Compatibility and 2018 IEEE Asia-Pacific Symposium on Electromagnetic Compatibility (EMC/APEMC), Singapore, pp. 793-797.

[b-Pretorius-2] Pretorius, P. H. (2018), *On in Situ Lightning Current Impulse Testing in a Large Free Field PV Plant*, 2018 34th International Conference on Lightning Protection (ICLP), Rzeszow, pp. 1-8.

[b-Pretorius-3] Pretorius, P. H. (2018), *Behaviour of Surge Protective Devices Under Lightning Ground Potential Rise: Findings from a Desk-top Study*, 2018 IEEE International Symposium on Electromagnetic Compatibility and 2018 IEEE Asia-Pacific Symposium on Electromagnetic Compatibility (EMC/APEMC), Singapore, pp. 817-820.

[b-Sekioka] Sekioka et al. (2007), *Lightning Overvoltages on Low Voltage Circuit Caused by Ground Potential Rise*, 2007 International Conference on Power Systems Transients (IPST'07) in Lyon, France.

Bibliography

[b-ITU-T G.9700] Recommendation ITU-T G.9700 (2019), *Fast access to subscriber terminals (G.fast) – Power spectral density specification*.

[b-ITU-T K.39] Recommendation ITU-T K.39 (2019), *Risk assessment of damages to telecommunication sites due to lightning discharges.*

[b-ITU-T L.76] Recommendation ITU-T L.76 (2008), *Copper loop requirements for various technologies including indoor and structured cabling*.

[b-ETSI TS 101 548-1] ETSI TS 101 548-1 V2.4.1 (2020-05), *Access, Terminals, Transmission and Multiplexing (ATTM); European Requirements for Reverse Powering of Remote Access Equipment; Part 1: Twisted pair networks.* <https://www.etsi.org/deliver/etsi_ts/101500_101599/10154801/02.04.01_60/ts_10154801v020401p.pdf>

[b-Cigre 549] Cigre 549 (2013), *Lightning Parameters for Engineering Applications.* <https://www.researchgate.net/profile/William-Chisholm/publication/271556629_CIGRE_technical_brochure_on_lightning_parameters_for_engineering_applications/links/5bdafbcca6fdcc3a8db585a9/CIGRE-technical-brochure-on-lightning-parameters-for-engineering-appli>

[b-Martin 2022] Martin, A.R. (2022), *The Effects GPR in a Suburban Environment, ATIS Protection Engineers Group (PEG): Electrical Protection of Communications Networks Conference*. <https://peg.atis.org/conference/library/2022-presentations/>

[b-MIL-HDBK-419A] MIL-HDBK-419A (1987), *Grounding, bonding, and shielding for electronic equipments and facilities*, (Handbook contains both volume I basic theory, and volume II applications). <https://www.wbdg.org/FFC/NAVFAC/DMMHNAV/hdbk419a_vol2.pdf>

[b-Pretorius] Pretorius, P.H. (2018), *Was lightning ground potential rise overlooked in the design of large earth electrodes*?, EE Publishers.

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