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SERIES K: PROTECTION AGAINST INTERFERENCE

Resistibility analysis of 5G systems

ITU-T K-series Recommendations – Supplement 8

Supplement 8 to ITU-T K-series Recommendations

Resistibility analysis of 5G systems

Summary

Supplement 8 to ITU-T K-series Recommendations analyses 5G system resistibility requirements for lightning and power fault events. The electrical threats posed by lightning and power fault events are discussed and the appropriate resistibility tests identified. Installation practice can have a significant influence on the reliability of services and equipment. Earthing, location and technical expertise are discussed.

History

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1 Scope

This Supplement looks at the electrical threats to the 5G network and its equipment resulting from lightning and power faults. The propagated electrical threat arriving at an equipment port needs to be mitigated and various mitigation methods are discussed. The applicability of various mitigation approaches is discussed as there is often more than a single mitigation solution. In the case of electrical transient surges such as lightning, achieving adequate equipment resistibility can result in the diversion or reflection of the surge stress. How this might be comprehended in associated equipment is discussed.

2 References

[ITU-T K.44] Recommendation ITU-T K.44 (2017), *Resistibility tests for telecommunication equipment exposed to overvoltages and overcurrents – Basic Recommendation*.

[ITU-T K.45] Recommendation K.45 (2017), *Resistibility of telecommunication equipment installed in the access and trunk networks to overvoltages and overcurrents*.

[ITU-T K.96] Recommendation ITU-T K.96 (2014), *Surge protective components: Overview of surge mitigation functions and technologies*.

[ITU-T K.98] Recommendation ITU-T K.98 (2014), *Overvoltage protection guide for telecommunication equipment installed in customer premises*.

[ITU-T K.99] Recommendation ITU-T K.99 (2017), *Surge protective component application guide – Gas discharge tubes*.

[ITU-T K.101] Recommendation ITU-T K.101 (2014), *Shielding factors for lightning protection*.

[ITU-T K.108] Recommendation K.108 (2015), *Joint use of poles by telecommunication and solidly earthed power lines*.

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

[ITU-T K.126] Recommendation ITU-T K.126 (2017), *Surge protective component application guide – High frequency signal isolation transformers*.

[ITU-T K-Sup.7] ITU-T K-series Recommendations – Supplement 7 (2017), *ITU-T K.44 – AC supply configurations*.

[IEC 62305] IEC 62305:2013 SER series, *Protection against lightning*.
https://webstore.iec.ch/publication/6797

[TB 549] Technical Bulletin (TB) 549 (2013), *Lightning Parameters for Engineering Applications*.

3 Definitions

None.

4 Abbreviations and acronyms

This Supplement uses the following abbreviations and acronyms:

EPR Earth Potential Rise

GDT Gas Discharge Tube

SPD Surge Protective Device

PE Protective Earth

PoE Power over Ethernet

5 Conventions

None.

6 Lightning

6.1 Lightning types

Cloud-to-ground lightning is normally classified into four types:

1. Negative lightning – Downward – leader – Median stroke waveform parameters: First: 30 kA, 5.5/75 and 5.2 C (waveform charge in Coulombs, see [TB 549]). Subsequent: 12 kA, 1.1/32, 1.4 C and is repeated 3 to 5 times with a 60 ms separation.
2. Positive lightning – Downward + leader – Median stroke waveform parameters: 35 kA, 22/230 and 16 C and 95% values for the total flash are 250 kA, 200/2000 and 350 C.
3. Negative lightning – Upward + leader – Relevant to tall structures, data available indicates typical charge values of 30 C.
4. Positive lightning – Upward – leader – Relevant to tall structures data available indicates typical charge values of 100 C.

Lightning type 1 forms the majority of lightning and lightning type 2 is altitude dependent but can be about 5% of total lightning activity. The tall structure lightning is very specific and data is still being gathered. Engineering values for lightning strokes and flashes (the complete lightning event) can be found in [TB 549]. A graphic illustration of the four cloud-to-ground lightning types is shown in Figure 1 with red for positive charge and blue for negative charge. Intra-cloud and inter-cloud lightning flashes also occur (estimated about 20%) and these can result in inductively coupled surges in metallic cables serving high altitude locations.

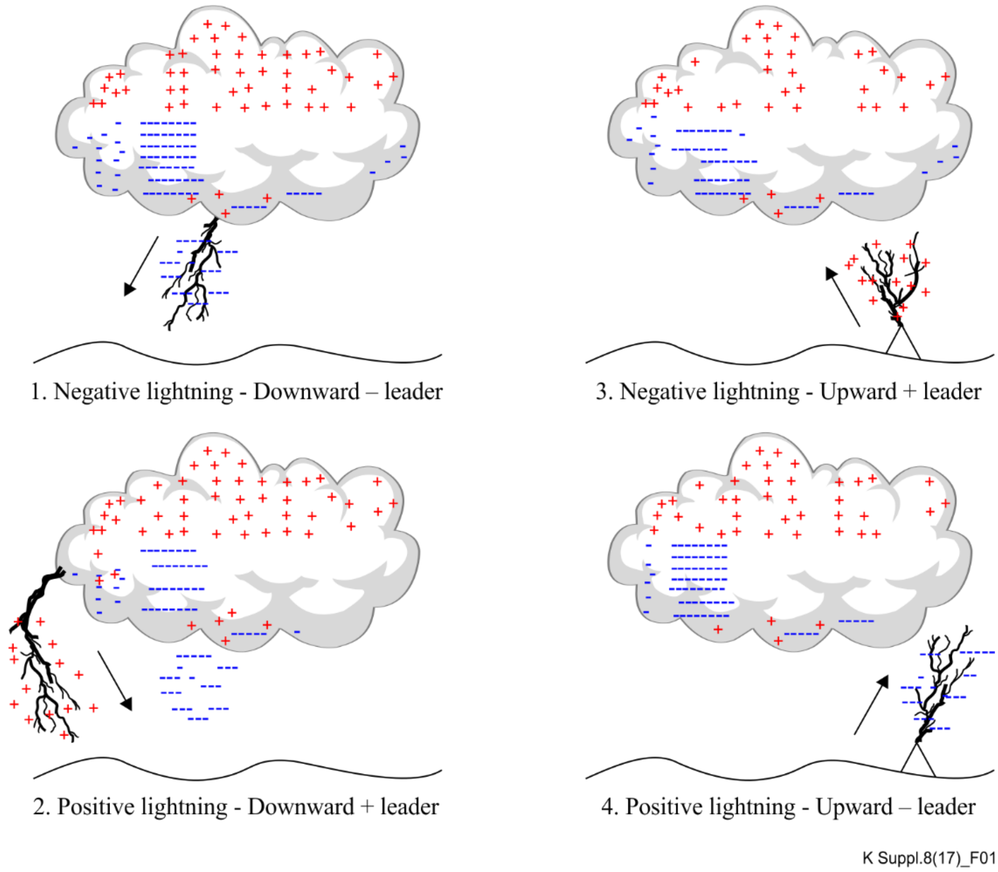


Figure 1 – Four cloud-to-ground lightning types

6.2 Lightning coupling

Protecting against a direct lightning stroke is practically impossible. By taking care as to where the cables and equipment are sited, the possibility of a direct strike can be made acceptably low. Methods of direct lightning diversion by a structure lightning protection system and the shielding effect of other structures are covered in [IEC 62305]. Mitigation measures concentrate on the indirect effects of lightning. Figure 2 is adapted from [ITU-T K.98] and shows several flash scenarios.

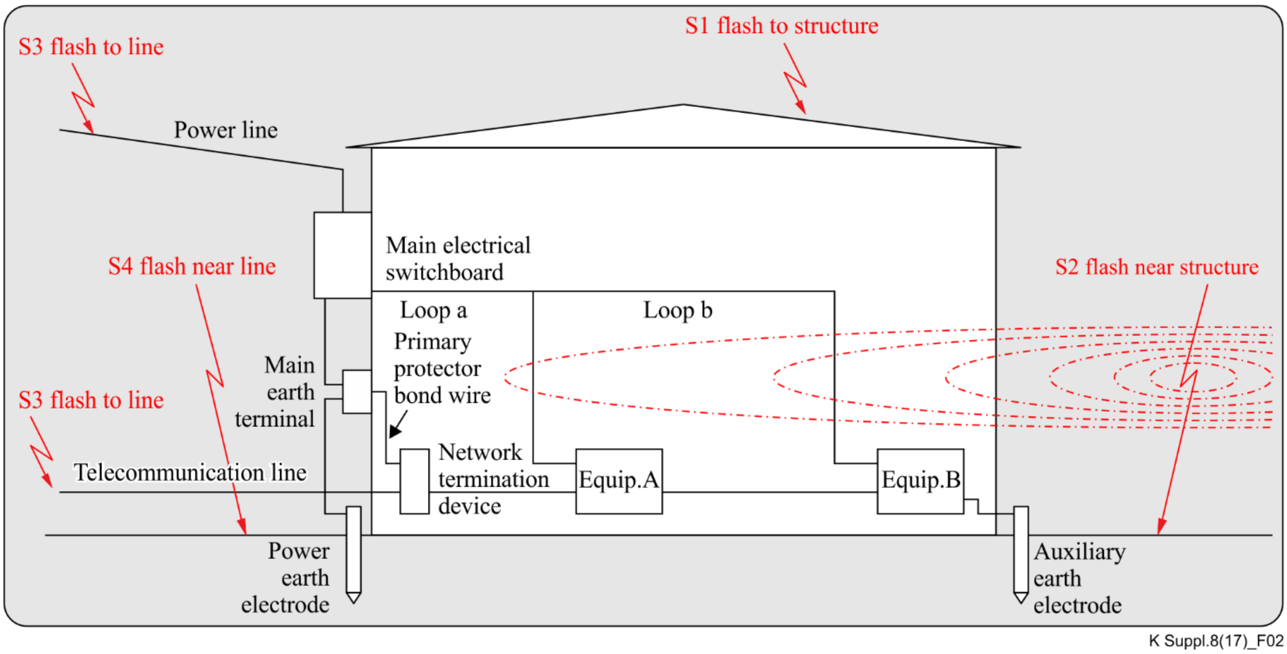


Figure 2 – Possible lightning flash coupling

- S1 flash to structure – strike to an air termination, antenna, metallic service pipe or to a conductor. The structure will rise in potential with respect to remote earth. Some 25% of the lightning current can flow in the structure metal work, which will magnetically couple into the structure wiring loops. The magnitude of the voltage induced into the internal cabling depends on many factors such as lightning strike current rate of current rise, closeness of the strike, size of the wiring loop, type of the cable and building shielding. Generally, as the coupling mutual inductance is low, such coupled surges are short, high in voltage, but relatively low on current.
- S2 flash near structure – the lightning flash to earth will cause an earth potential rise, which is likely to change the earth potential at the structure. The flash magnetic field will couple into the wiring loops within the structure, the same as the S1 flash.
- S3 flash to line – conductive coupling occurs when the flash strikes the telecommunication or power service line or cable. Although prevalent in overhead lines, lightning strikes to earth can seek out buried cables as they are good conductors. Surge voltage limitation will occur either because of insulation breakdown or the operation of a surge protective device (SPD). Diverting the high currents to earth will cause earth potential rise and differential protective earth voltages within the structure.
- S4 flash near line – causes a rise in earth potential that may be significant at the structure. The lightning rate of current rise of current will couple a short duration voltage impulse into the line. However, the impulse current capability will be relatively low.

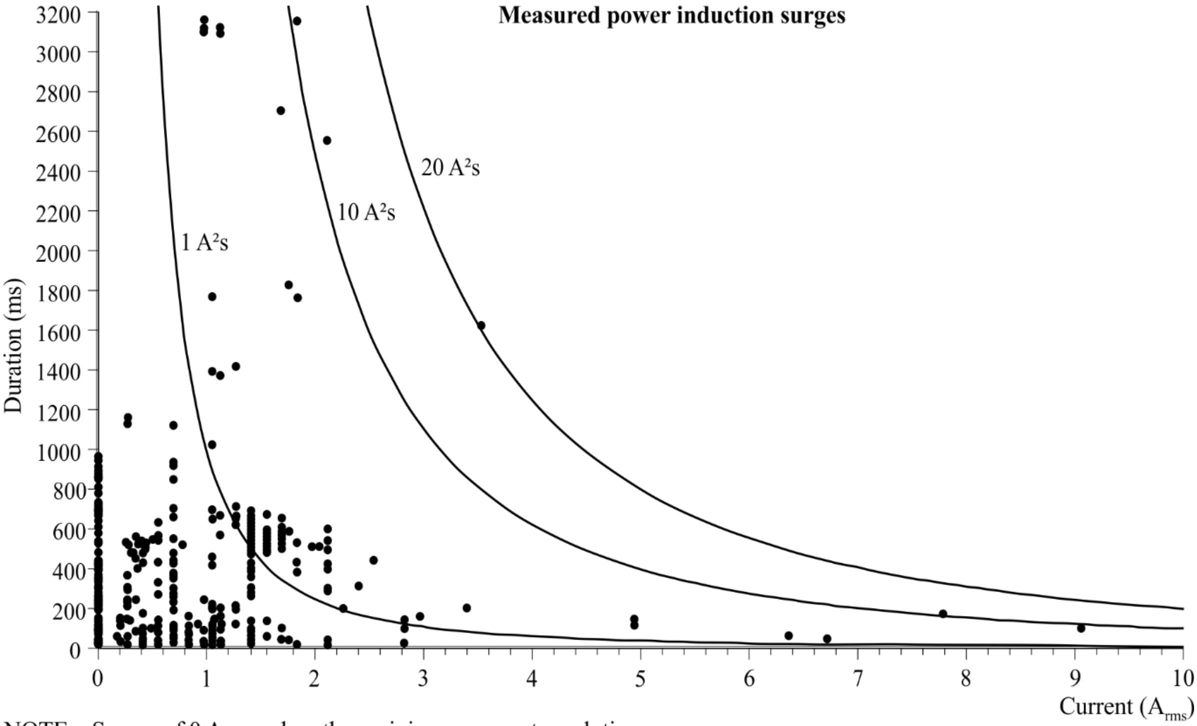
7 Power faults

7.1 Power cross

Power cross is the situation where the power distribution line contacts the telecommunications line. This event was postulated for overhead lines having power distribution and telecommunications lines. This is not so much the norm today. The resistibility test consists of applying the local AC mains supply voltage (typically 110 V or 230 V) to the metallically wired telecommunications port.

7.2 Power induction

When a major current fault occurs in an AC power distribution system, high currents will flow until distribution disconnector operates. Generally, it is assumed such faults do not last much longer than a few seconds. Metallic telecommunications cables that run parallel with the distribution line for some distance will be subject to the magnetically coupled fault current. Figure 3 adapted from [ITU-T K.44] shows induction records taken in Australia.



NOTE – Surges of 0 A were less than minimum current resolution.

Figure 3 – Power fault induction currents

8 Surge propagation to and through the equipment

The path from the surge source point to the equipment conditions the equipment port surge. If the equipment diverts the surge current into other paths, which have inductance, then the equipment connection to that path will develop a voltage. The availability of an earthing system depends on the mains distribution system, see [ITU-T K-Sup.7].

To understand the propagation of surges and how they change wave-shape and where the currents go needs a complex analysis. [ITU-T K.98] is a good reference work to understand such things. [ITU-T K.98] includes over 30 customer premises 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 [TB 549]. The lightning strike is assumed to be either to the telecommunications line or the AC mains supply. The document considers mains configuration types of TN-S, TN-C, TN-C-S, TT and IT. The effects of various earthing system lead lengths and earth electrode resistances are also analysed.

9 Mitigation methods

There are two types of surge, common-mode and differential-mode. Most surges are in common-mode, but insulation breakdown and voltage-limiting type SPD operation can convert a common-mode surge into a differential surge. Common mode means all the service conductors have the same level of surge (equipotential). Figure 4 shows several mitigation options for a common-mode surge:

a) voltage limit the surge voltage from a reference potential (usually earth) by using voltage limiting components,

b) block the voltage surge with an isolating transformer, which cannot apply to the telecommunication services carrying DC voltage such as power over Ethernet (PoE),

c) filter out the surge frequencies if the service and lightning spectrums do not overlap,

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

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

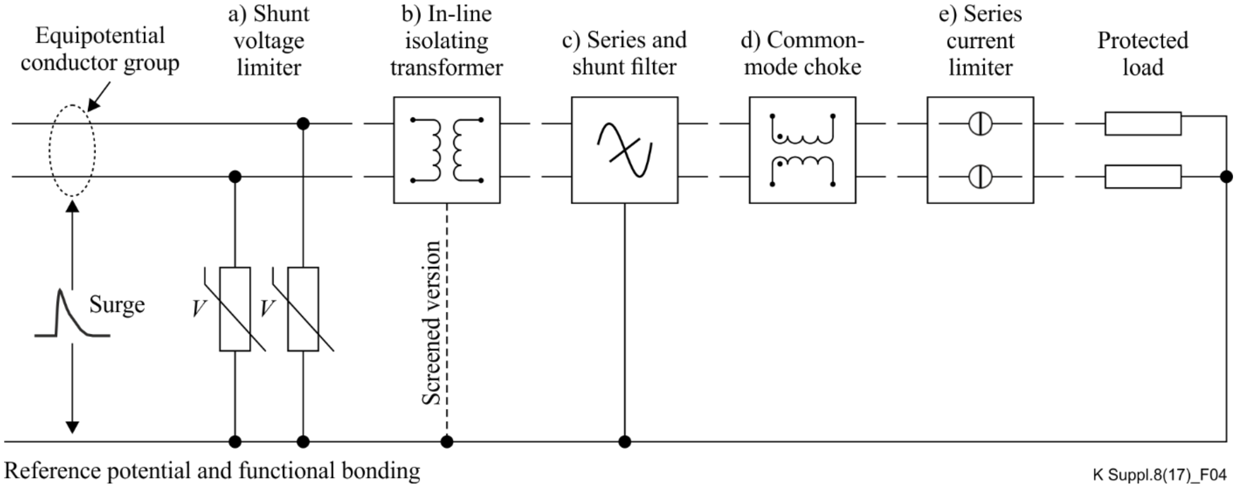


Figure 4 – Common-mode surge mitigation options

The description and operation of protection technologies is covered in [ITU-T K.96].

Differential mode means that the surge voltage is developed between the service conductors. Figure 5 shows several mitigation options for a differential-mode surge:

a) voltage limit the surge voltage between the conductors by using voltage limiting components,

b) if the signal transformer core saturates, stopping transformer action, surge truncation will occur, see [ITU-T K.126],

c) filter out the surge frequencies if the service and lightning spectrums do not overlap,

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

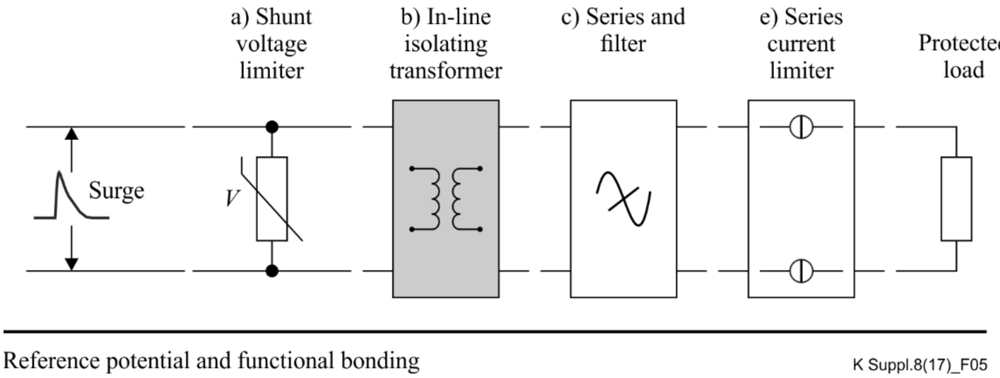


Figure 5 – Differential-mode surge mitigation options

10 Lightning surge diversion

When a common-mode surge is mitigated by voltage limiters to the local functional bonding (see Figure 4-a) the resultant surge current flows in that bonding. If a star powering configuration is used with a central power distribution point and one terminal suffers common-mode surge, possibly due to an earth potential rise (EPR), that surge propagates to the central distribution point. If the central distribution point does not have an effective earth connection, the central distribution point equipment functional bonding will have a surge voltage. This surge voltage can then be transferred to the other equipment terminals. This means it is possible to have the surge at one terminal transfer to the other terminals via the central distribution equipment. [ITU-T K.118] gives an example of surge diversion.

11 5G resistibility

11.1 Communications port

For the 5G data capacity needed, fibre communications is an obvious choice. This communications medium is inherently isolated and does not need protection. However, a badly installed fibre metallic trace wire is a path for lightning entry. Figure 6 shows evidence of three separate arc paths. To breakdown the gaps, lightning voltages in the region of 30 kV must have occurred. The safest solution is to use a fibre trace wire that is not continuous but is in segments, or is non-metallic.

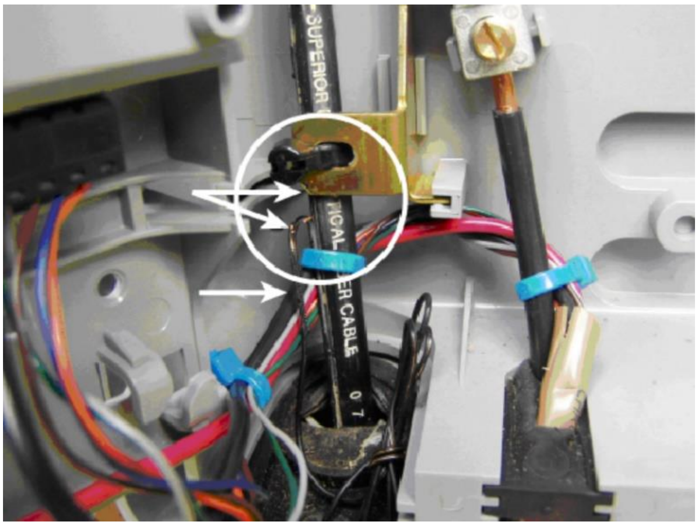


Figure 6 – Evidence of three arc paths from badly installed fibre metallic trace wire (photograph courtesy of ADTRAN)

Wireless communication is another medium that is inherently isolated and only needs protection if the aerial is exposed.

Wired communication mediums need careful thought as to their protection needs. Coaxial cable is unlikely to need protection if the screen is connected the functional bonding of both pieces of equipment. If an equipment is class II (floating) then an earth bonding during a surge may be desirable as described in [ITU-T K.99] and shown in Figure 7.

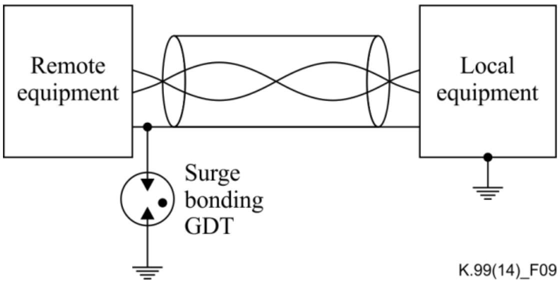


Figure 7 – Gas discharge tube (GDT), earth bonding during a surge

Ethernet and PoE rely on the insulation voltage withstand to block the common-mode surge voltages, it is vitally important to know the surge environment maximum voltage to define the needed insulation voltage withstand.

11.2 Location

As explained in clause 6.2 the equipment should be installed where it is shielded against direct strikes. For more information on shielding see [IEC 62305] and [ITU-T K.101]. Where there is joint use of poles by telecommunication and solidly earthed power lines the minimum clearance distances given in [ITU-T K.108] should be observed.

11.3 Power port

Unless the equipment has its own powering source, remote AC or DC powering is necessary. The metallic powering cable could be prone to lightning coupling and EPR, if cable SPDs are used. If the equipment has a protective earth (PE) connection EPRs could be introduced. Selection of appropriate protective means can be made through reference to clause 9.

11.4 5G equipment classification

The bulk of 5G equipment will be classed as access equipment and the Recommendation that covers the resistibility of such equipment is [ITU-T K.45]. However, certain other aspects such as location, installation and provision of adequate earthing, when required, need to be understood.

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