Raycap

Considerations in the Protection of Cellular Radio Sites

The need for effective lightning and surge protection on telecommunications towers regardless of configuration and geographic location can not be underestimated. This paper presents evidence to support the above statement.

1. Introduction

The merits of installing effective lightning and surge protection on telecommunications towers, along with adopting good grounding and bonding practices are well established.

Tower structures are often elevated above their surroundings in order to maximize coverage, thereby making them attractive lightning receptors to the vagaries of the Cloud-to-Ground lightning discharge. The conventional Lightning Protection System (LPS) consisting of strike receptor, lightning downconductor and low impedance ground termination system is well defined in standards such as NFPA 780[1] and IEC 62305.

Standards such as IEC 61643 on the other hand, cover the need for overvoltage surge protective devices being installed to safeguard sensitive electronic equipment. With the advent of relocating the radio units from the base shelter to the tower-top, the exposure to the influences of the electro-magnetic impulse created by direct or nearby lightning discharges has also increased significantly. Such tower-top systems are particularly vulnerable to induced voltages onto DC power feeders.

This paper sets out to explore a number of topical questions commonly posed regarding the scope of protection needed for different sites and locations. It seeks to provide background to each question, explaining the mechanism of the risk involved, and the method best suited to reduce this. It also covers aspects such as whether protection is required in geographic locations where isokeraunic levels are low, whether protection is needed when the site is surrounded by structures of equal or greater elevation, whether it is necessary to protect both the base station and the remote radio head, and how best to protect against the direct and indirect strike.

Interesting material dealing with some non–typical storm data is also presented to provide a degree of caution to the design engineer that even in locations where the annual average of thunder day activity is generally low – such as the west coast of the USA – occasionally atypical events of nature can occur and cause just as much damage in a few hours as would normally only be expected in locations of high annual isokeraunic activity.

Finally, the paper introduces the concept of "zones of protection" as defined in the IEC 62305 series of lightning standards, and describes how this practical approach (using magnetic screening and surge protection measures) can be applied to establish "safe" zones for the RRH and BBU, where exposure is reduced to within their operation withstand level.

Contents

1. Introduction 1
2. Is surge protection needed on every site, regardless of the tower height? 2
3. Do I need to deploy OVPs in sites located on the West Coast, ... given the low lightning activity of that area? 5
4. What is the projected lightning activity in the US region for the future? 7
5. How should a cellular tower site be protected against direct and indirect lightning events? 8
6. Is protection required on rooftop locations even when surrounded by taller buildings? 12
7. Is external protection required even if radios incorporate this internally? 13
8. What is the required surge rating of SPDs used in the protection of RRHs and BBUs? 14
9. What protection measures against lightning are used in other applications? 14
10. Conclusions 15
11. References 15

2. Is surge protection required on every site, regardless of the tower height?

Recent research has provided positive correlation between an increase in the local lightning ground flash density with incidence of elevated man-made structures such as telecommunication towers, high-rise buildings, wind turbines and similar.[2] In addition, correlation has also been observed between the number of cloud-to-ground (C-G) flashes and the urban density of taller structures, which are becoming more common in today's metropolitan cities.

For example, geographic areas with a high density of towers exceeding 200 ft are shown to experience up to 150% increase in Cloud-to-Ground flashes when compared to their surroundings 2 km to 5km away, where the incidence of tall structures drops off.[2]

Such observations speak to the growing need for effective protection against the increasing incidence of lightning as our cities and infrastructure become denser and more elevated.

The direct lightning strike is all too apparent as one of nature's more dangerous events, capable of causing extensive physical damage to structures and sensitive electronic equipment. This occurs with the deposition of many Coulombs of charge from the cloud to the ground, during which many thousands of amperes flow. This however is only one deleterious side to the lightning event – the extremely fast rise-times associated with the current impulse (known as di/dt), means that it is able to very effectively couple destructive energy to adjacent conductors. This process usually takes place through magnetic induction, capacitive coupling, or direct galvanic connection. Such indirect effects are even more common, and may cause significant damage if not properly mitigated through effective surge protection measures.

To minimize the effects of the electro-magnetic pulse (EMP) of the lightning discharge, the structural shielding is often used.[3] While this can reduce the direct influence of the impulse, it cannot eliminate the induction phenomena onto adjacent cabling and conductors feeding sensitive equipment, such as the electronics in the Base Band Unit (BBU) and the Remote Radio Head (RRH). To reduce these inductive effects, Surge Protective Devices (SPDs) are installed.

The IEC 62305-2 standard provides a method to estimate the probability of direct and indirect lightning strikes related to a structure's height and the local ground flash density.[3]

To quantify the above, we consider the following example: Assume that Colorado (a US state with lightning activity of 4.9 CG/mi2/year, which is below the US average) has 1000 towers exceeding 300 ft in height and located in exposed rural areas. Then according to the IEC method described in "*Antenna structures and cloud-to-ground lightning location,*"[3] every year we can expect:

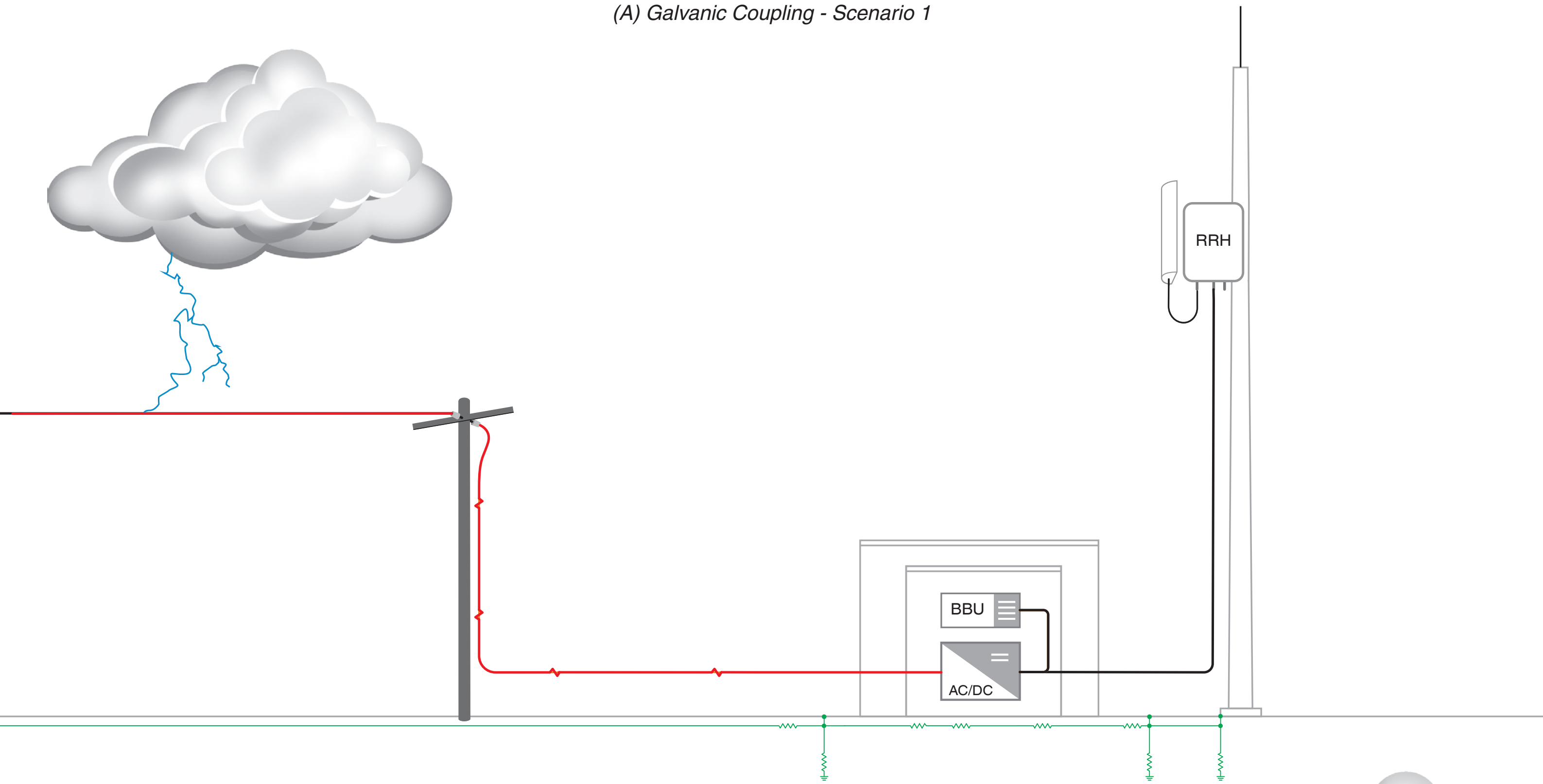
- **1138 direct strikes to the towers,**
- 3876 nearby strikes that will induce surge currents onto the electrical power system in the vicinity of the sites,
- 196 direct strikes to the utility power lines supplying the towers,
- 19600 nearby strikes that will induce surge currents to the utility power lines supplying the towers.

Assume next that the 1000 towers are now only 100 ft in height and again located in exposed rural areas. Then, according to the same method, every year we can expect:

- **130 direct strikes to the towers,**
- 3876 nearby strikes that will induce surge current onto the electrical power system in the vicinity of the site,
- 196 direct strikes to the utility power lines supplying the towers,
- 19600 nearby strikes that will induce surge currents to the utility power lines supplying the towers.

From this, it is evident that the height of the tower is important in as far as its exposure to direct lightning strikes, while its influence on induced overvoltages due to nearby strikes, remains largely unchanged. This leads us to conclude that there is a need for effective overvoltage protection on both tall and short towers alike.

(A) Galvanic Coupling - Scenario 1



(A) Galvanic Coupling - Scenario 2

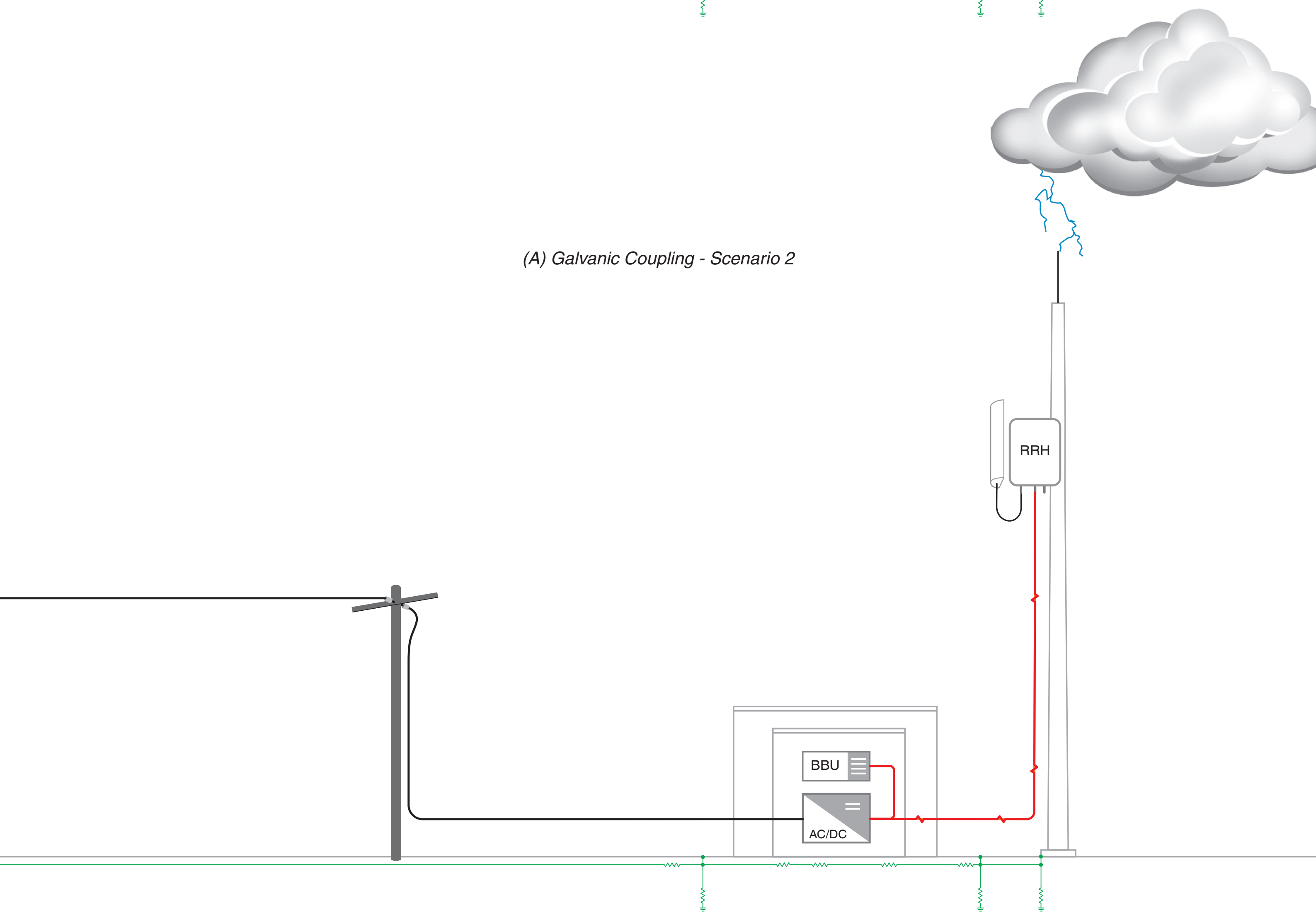
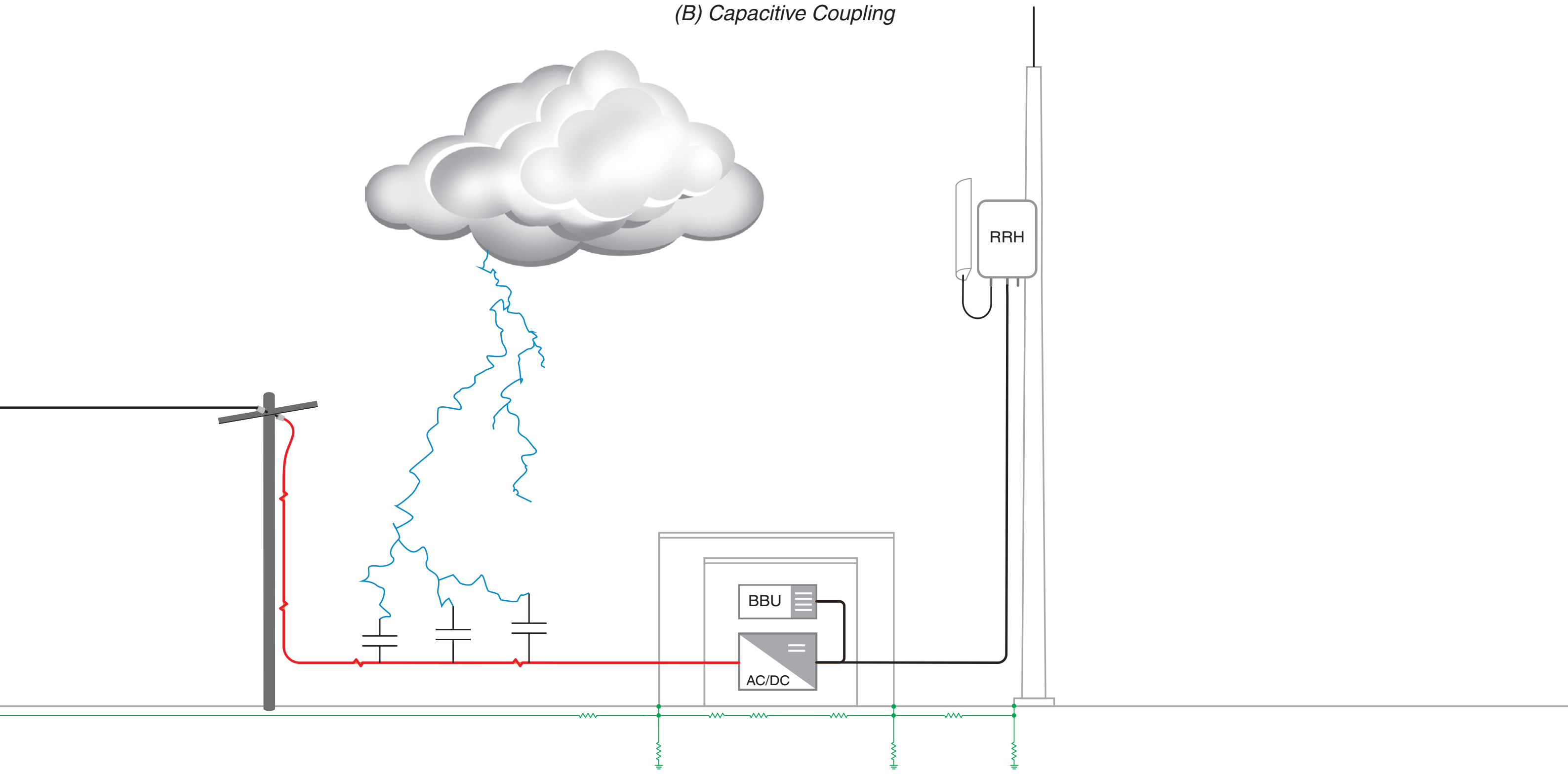
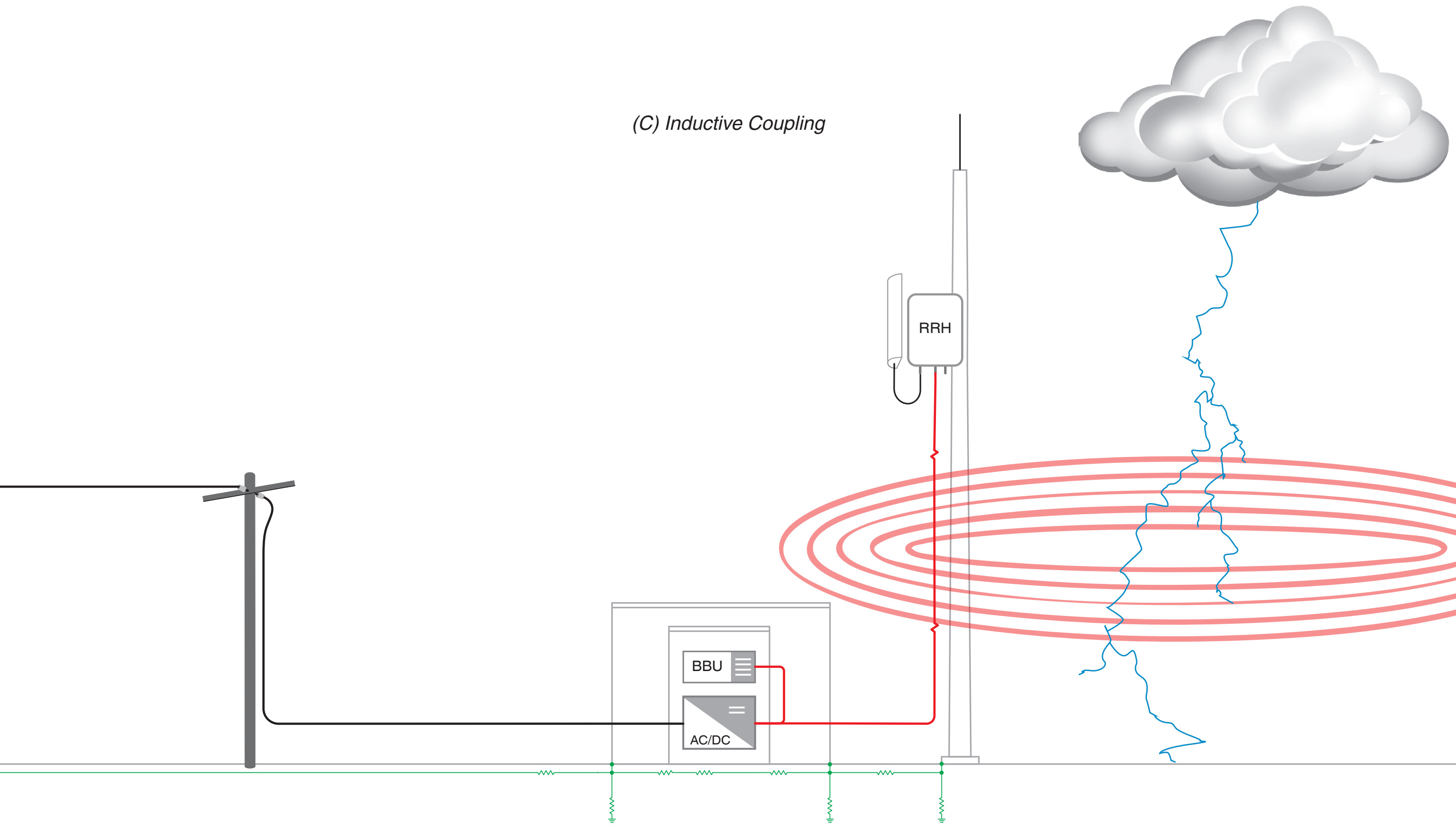


FIgure 1: Representation of 3 different types of induction effects due to lightning event.

(B) Capacitive Coupling



(C) Inductive Coupling



3. Do I need to deploy OVPs in sites located on the West Coast, given the relatively low lightning activity of that area?

Monitoring of cloud-to-ground flash densities started in the USA in 1989 when the National Lightning Detection Network (NLDN) was first deployed across the continental US.[4] Since this time, the system has undergone improvements in accuracy and accessibility, and continues to provide extensive lightning data such as: location, amplitude, polarity and frequency. Many scientific papers have been published analyzing data from the NLDN. In addition the data has been used to generate ground flash density maps (isokeraunic maps) which have proved useful in lightning strike probability calculations.[3]

Lightning Protection standards such as IEC 62305-2 and NFPA 780, deal with Risk Management and Mitigation. Both standards provide methods of evaluating the effective risk R to a structure, and compare this to the Tolerable Risk R_T for that site (expressed in tolerable events per year). These methods take a number of inputs including: ground flash density Ng (NLDN in the USA), exposure of the site, nature of the equipment and/or occupants and the risk of damage and loss.

The risk of damage and consequential losses are usually broken into 4 categories:

- L1 Loss of human life
- L2 Loss of service to the public
- L3 Loss of cultural heritage
- L4 Loss of economic value

Telecom services are generally exposed to Losses L2 and L4.

Subsets of these losses include:

- Loss due to failure of power systems (flashes direct to, or near to, a service)
- Loss related to failure of internal equipment (flashes near a service)
- Loss of critical public services (includes communications and 911 sites)

Risk assessment of telecommunications facilities using the methods laid out in IEC 62305-2, generally result in risks exceeding tolerable levels to both equipment and services. This outcome is noted when the calculations are performed for sites:

- Located in areas of high or low isokeraunic exposure, and
- Deemed to be exposed, or
- Surrounded by adjacent structures of equal or greater height.

The reason for such outcomes is generally due to the risk posed by the long DC cable lengths, which in the calculations contribute significant risk to the site's cumulative Risk R. This is a result of the significant induced voltages developed along such conductors when exposed to the electro-magnetic pulse (EMP) of nearby lightning discharges. With the advent of tower-top RRHs, the longer DC feeder cables serve as antennas to EMP induced currents.

Mitigation measures then need to be applied to reduce the site's risk $R < R_T$. These measures include:

- Shielding (reducing exposure to the electro-magnetic effects of near-by lightning discharges)
- Bonding (reducing the effects of equi-potential gradients during the lightning event)
- Surge and overvoltage protection (reducing voltage stress to levels below the impulse withstand Uw of the equipment)

While the various Risk Management models provided by international lightning protection standards may be useful tools to assess the risk exposure of a particular structure, it is important to remember that these are only models accurate to the first or second order, and as such, cannot fully compensate for the many variabilities of this phenomenon of nature.

For example, while the average annual ground flash density Ng, for the particular geographical area where a cellular tower is located may be low - and this may at first lead to assumptions that $R < R_T$ - the actual ground strike distribution can be unduly intense over a particular period of the year, or even during just one storm.

To emphasize the point that even geographical regions with low mean annual flash densities can experience unseasonably high peaks, a recent headline dated 4/25/2018 noted *"India state records 36,749 lightning strikes in 13 hours!"*[5] The article went on to explain that the southern Indian state of Andhra Pradesh recorded this anomaly while data from prior years showed less than this number of strikes throughout the entire month in the same region.

Figure 2 shows the degree to which the ground flash density varies across the continental USA. California is seen to have an average CG flash density of 0.5 CG/mi2/year while Florida has over 20 CG/mi2/year.[6]

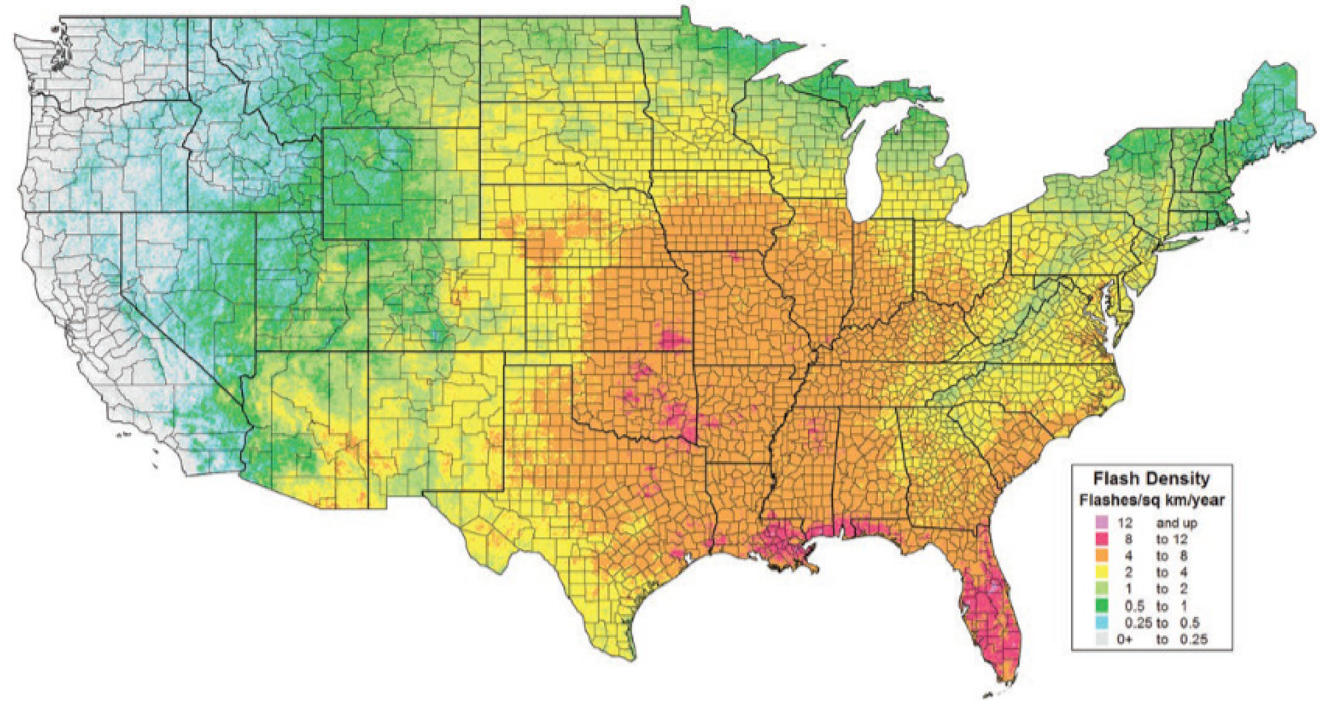


Figure 2: Ground flash density in US for 2007-2016.[6]

Figure 3 provides a view of the typical C-G flash distribution during common storm activity. While this can be seen to correlate reasonably well with the flash density map of Figure 2, it can be misleading to assume that infrastructure located in these areas of low average isokeraunic levels will only experience low lightning activity, and as such are not at risk.

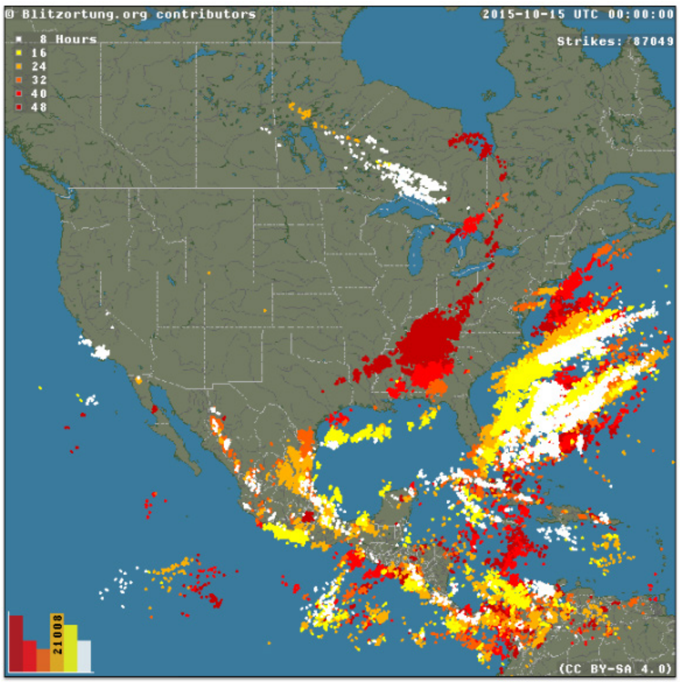


Figure 3: Typical distribution of CG events during stormy weather across US.[7]

Of late, more intense and localized storms have been experienced throughout the US. Some have attributed these changes in historical weather patterns to climatic changes, but whatever the reason, it is becoming difficult to assure that structures in regions of low isokeraunic activity will not experience intense isolated events during the course of their operational lifetime. The need for effective protection measures are just as important during such times, as they are in those sites located where the norm is to experience high storms activity through the summer months.

An example of this occurred on October 15, 2015, when a large thunderstorm originating in the Gulf of Mexico reached as far west as the California coast with intense localized C-G discharges and caused severe damage to infrastructure - Figure 4. Scientists maintain that we can now expects such extreme events to occur on an annual basis.

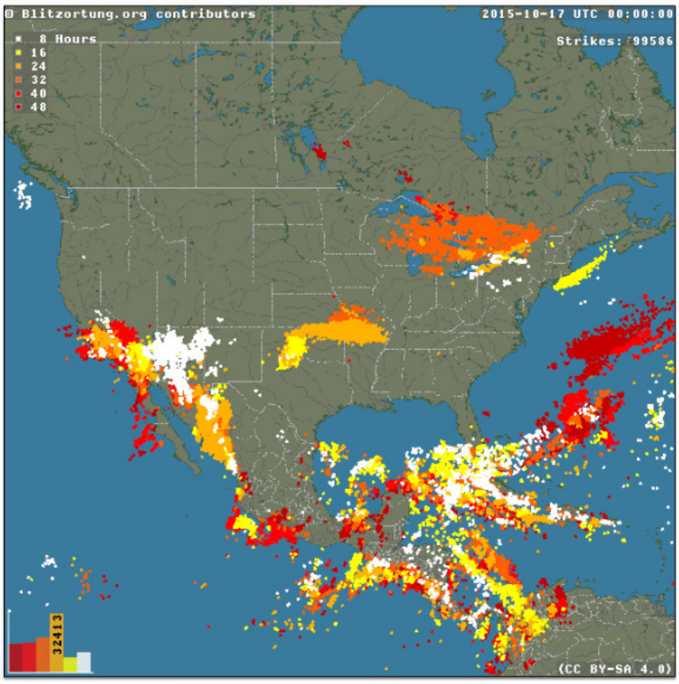


Figure 4: Distribution of CG events across the US and California on 15.10.2015.

Total number of recorded CG events was 99586.[7]

In summary, a severe localized storm can create as many strikes in a few hours as the annual average for that area, and so the incident risk, and consequential need for protection, cannot be based solely on annual thunder day maps. In addition, there is no correlation between the lighning strike density (Ng) of a particular geographical area, and the intensity of the strikes themselves (kA). Lightning events (strikes) of significant intensity may just as easily occur in areas of low annual average lightning density, as in regions where the storm activity can exceed 200 days per year. For this reason, operators should ensure that sound engineering measures are followed and overvoltage protection provided whenever sensitive electronics systems are relied upon, irrespective of isokeranunic indicators.

4. What is the projected lightning activity in the US region for the future?

An underlying connection between temporary short-term climate variations and an increase in the frequency and severity of atmospheric activity, is generally noted.[8,9] Severe isolated events which previously would be expected to occur once in a lifetime, are now expected to occur at least once per decade or more frequently. This increasing risk factor is also changing our understanding of the importance of lightning damage mitigation and the need for effective over-voltage protection.

Our historical understanding that only elevated structures, in areas of high isokeraunic activity are at risk from lightning, is now changing. The presence of severe weather activity across geographical areas previously unaccustomed to such events (such as the west coast of the USA) is being acknowledged, and the need for effective overvoltage protection where sensitive electronic systems are installed, is unquestioned by engineers and site operators alike.

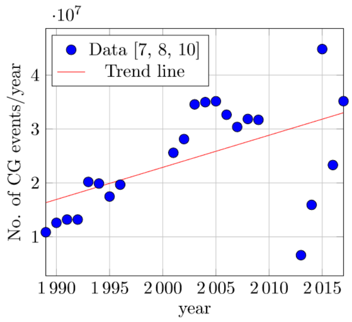
Indeed, the increasing unpredictability of our atmospheric activity is rendering historical thunder day maps, such as those derived by the NLDN over the last 10 years of data collection, relatively inaccurate. This in turn is making the role of engineers more difficult when trying to calculate present day risk.

A comparison of present day CG flash density data [10,11] to more historical data[10] also provides some evidence for an increase in the average number of CG events. There is also some evidence for the position that these events are increasing year-over-year, but more commonly accepted is that this increase is typified by a few isolated, severe and unpredictable events.

Figure 5 shows the annual number of CG events from 1989 to 2017. With exception of 2013 having unusually low lightning activity, the general trend is observed to be increasing. The maximum number of CG events (45 millions) was recorded in 2015. According to "*Projected increase in lightning strikes in the united states due to global warming,*"[12] lightning strikes in the US are predicted to increase about 50% over this century.

Figure 5: Lightning activity over continental us in past 3 decades.

The number of annual CG events indicates positive trends



The data of Figure 5 again emphasizes that mean CG data alone should not be taken as a good measure of risk, or exposure. Even if the average number of CG events through a year in a certain location is moderate, it may also be very intense around one or two unseasonable storms during that year.

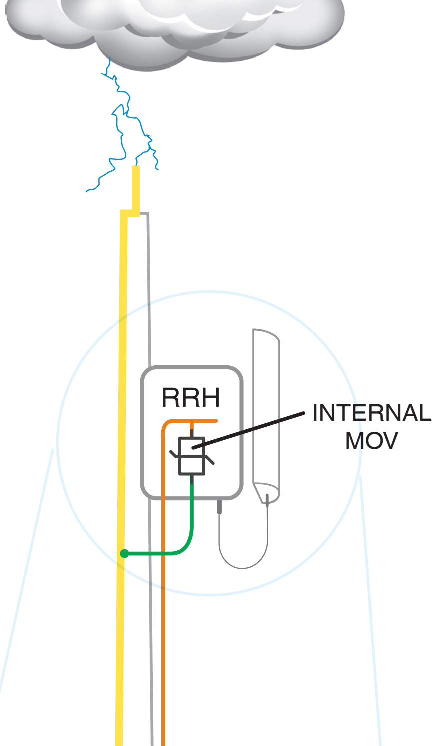
[8]Isolated events - Thunderstorms of such proportions not common for specific land areas.

5. How should a cellular tower site be protected against direct and indirect lightning events?

Protection of a tower site against damage caused by either direct or indirect lightning events, requires the use of a **Lightning Protection System (LPS)** to achieve the following:

- divert the majority of direct or induced lightning current safely to the ground, and
- keep large amounts of excess current away from sensitive electronics installed at the site, and
- limit the lightning surge events and overvoltages developed during lightning events to a level low enough that it can be tolerated by the electronic equipment.

The LPS comprises a **strike termination point** at the tower-top, insulated or non-insulated **down-conductor**, low impedance **grounding system** and **surge protective devices (SPDs)** also referred to as **Over Voltage Protectors (OVPs)**. During a direct lightning strike the current will be distributed typically as shown in Figure 6.



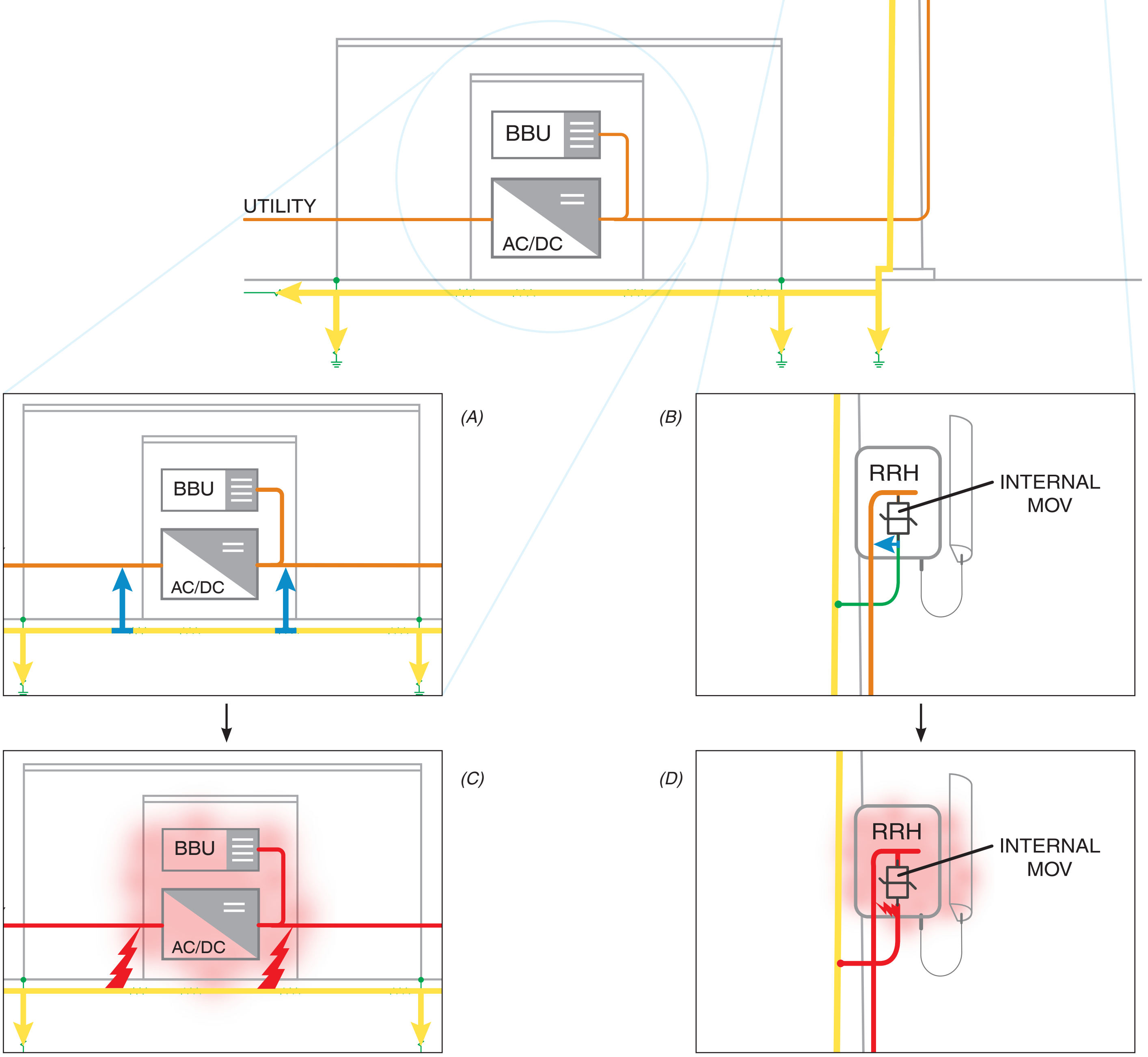


Figure 6: in (C) the expected overvoltage points are presented that will damage the corresponding equipment (D) Typical distribution of lightning current during a direct lightning strike on the tower (A,B).

The modelling of the lightning current flow from the strike point to the ground via the LPS, allows engineers to calculate voltage potentials which are created between various points of the LPS and adjacent current-carrying paths (such as the aircraft warning light cables, the low voltage DC power feeding cables to the RRH's etc).

This further provides for the selection of the points where SPDs need to be installed in order to ensure that, not only the lightning current is diverted away from where sensitive electronics are located, but that overvoltage levels on power and signal cables feeding the electronic equipment are maintained below the equipment's safe operational withstand level.

One may consider that the role of an LPS is similar to that of a network of water pipes and valves installed in a vertical structure. The lightning current is equivalent to the flow of water from the top of the structure with the aim of reaching the ground via gravity. The down conductors play the role of the water pipes. The SPDs serve a similar function to that of the water valves i.e. they regulate the flow of the water and divert it to the appropriate pipes.

The need for effective overvoltage protection on facilities housing sensitive electronics is well acknowledged in the industry - not only from the perspective of this being sound engineering practice, but also from the perspective that it makes good economic sense to protect the capital infrastructure and ensure trouble-free and uninterrupted operations. Any design of a cellular site without the incorporation of SPDs in front of electronic equipment, or any move to eliminate these protection measures from one point in the overall system, can provide a weakness to the overall security of the site. An LPS is effective in protecting a cellular site as long as it includes all the necessary components (as described above – lightning rod, down contactors, grounding system and SPDs). Not including, or arbitrarily removing, any of these LPS components, seriously compromises its effectiveness and puts the site at greater operational risk.

In the selection of SPDs appropriate for installation at a cellular site, one needs to consider the operational characteristics of the equipment to be protected as well as the location where the equipment and the SPDs will be installed. In locations where exposure to direct lightning current is possible, only Class I SPDs should be considered as these have been tested according to IEC-61643-11 to withstand the energy level associated with direct or partially direct lightning currents. Class II SPDs may not be able to handle the large amount of energy and are typically installed in areas where only induced currents are to be expected.

International standardization committees have been working for decades to create and maintain standards and guidelines that help engineers design the LPS for various complex installations. These guidelines are naturally applicable to the case of cellular sites. A very successful method of analyzing and simplifying the design of LPS is based on the principle of Lightning Protection Zones (LPZs), which is detailed in IEC 62305-1 and IEC 62305-4. In particular, and through the use of shielding, lightning current down conductors, grounding plates/electrodes and SPDs, three different types of LPZs can be created at the site, defined as follows:

- **LPZ 0**: Zone in which a direct lightning strike can attach to the structure.
- **LPZ 1**: Zone created by the installation of Class I SPDs at the LPZ 0-1 boundary to reduce exposure to the equipment within LPZ 1 from the direct lightning current. The over voltage levels within LPZ 1 may still be too high to adequately protect sensitive electronics.
- **LPZ 2**: Zone where the voltage levels are low enough for **electronics applications**. This reduced treat level is achieved by installing a second SPD rated to test Class II with low voltage protection rating.

Note: An SPD which is rated both test Class I and test Class II with low protection level, can adequately perform the function of reducing treat levels from LPZ 0B to LPZ 2 in one step.

Note: Low voltage electronics should only be installed in LPZ 2, or lower, zones.

Figure 7 shows the application of the LPZ method in the case of a cellular site with RRH's and BBU's and the appropriate installation point of SPDs for the protection of this sensitive electronic equipment.

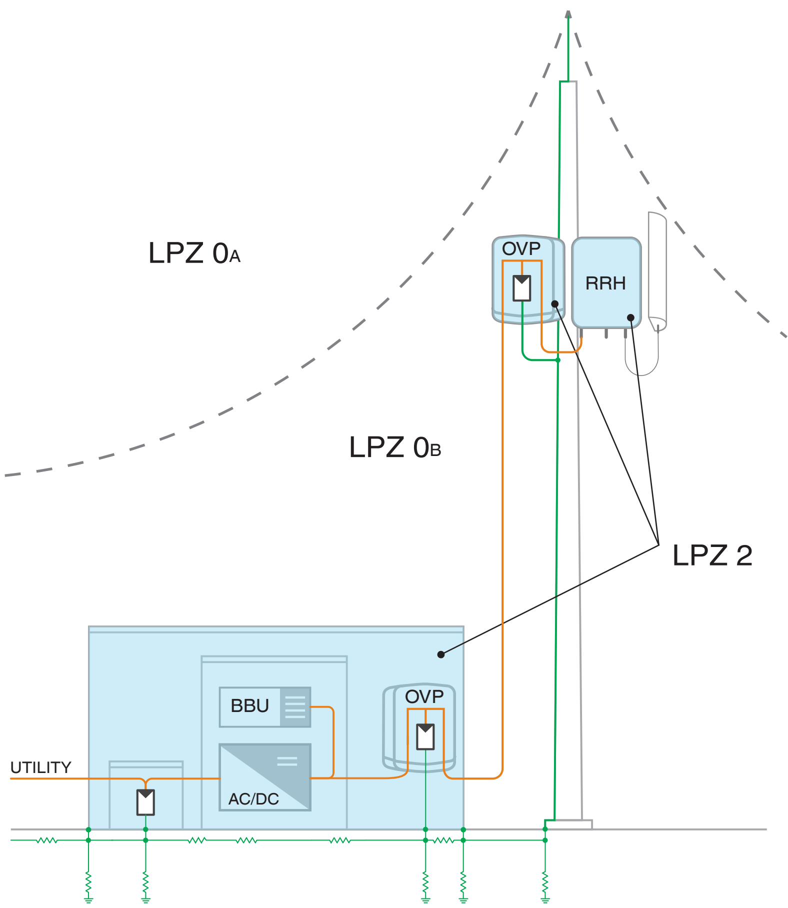


Figure 7: Lightning protection zones of a cellular site and appropriate installation points of SPDs for the protection of sensitive equipment.

In Figure 7, the RRH is installed/attached to the tower below the LPS strike termination rod (Franklin Rod). This is a location with typical LPZ 0B exposure, which is characterized by extreme lightning currents and electro-magnetic fields. The metallic shield of the RRH enclosure, in combination with an SPD at the power cable entry, creates a zone LPZ 2 inside the radio enclosure, where the sensitive electronics are located. In this LPZ 2, the effects of the electro-magnetic field are reduced to a level that can be tolerated by the electronics. It is important to observe that any SPD integral to the radio does nothing to reduce exposure simply because it is already within the metallic enclosure.

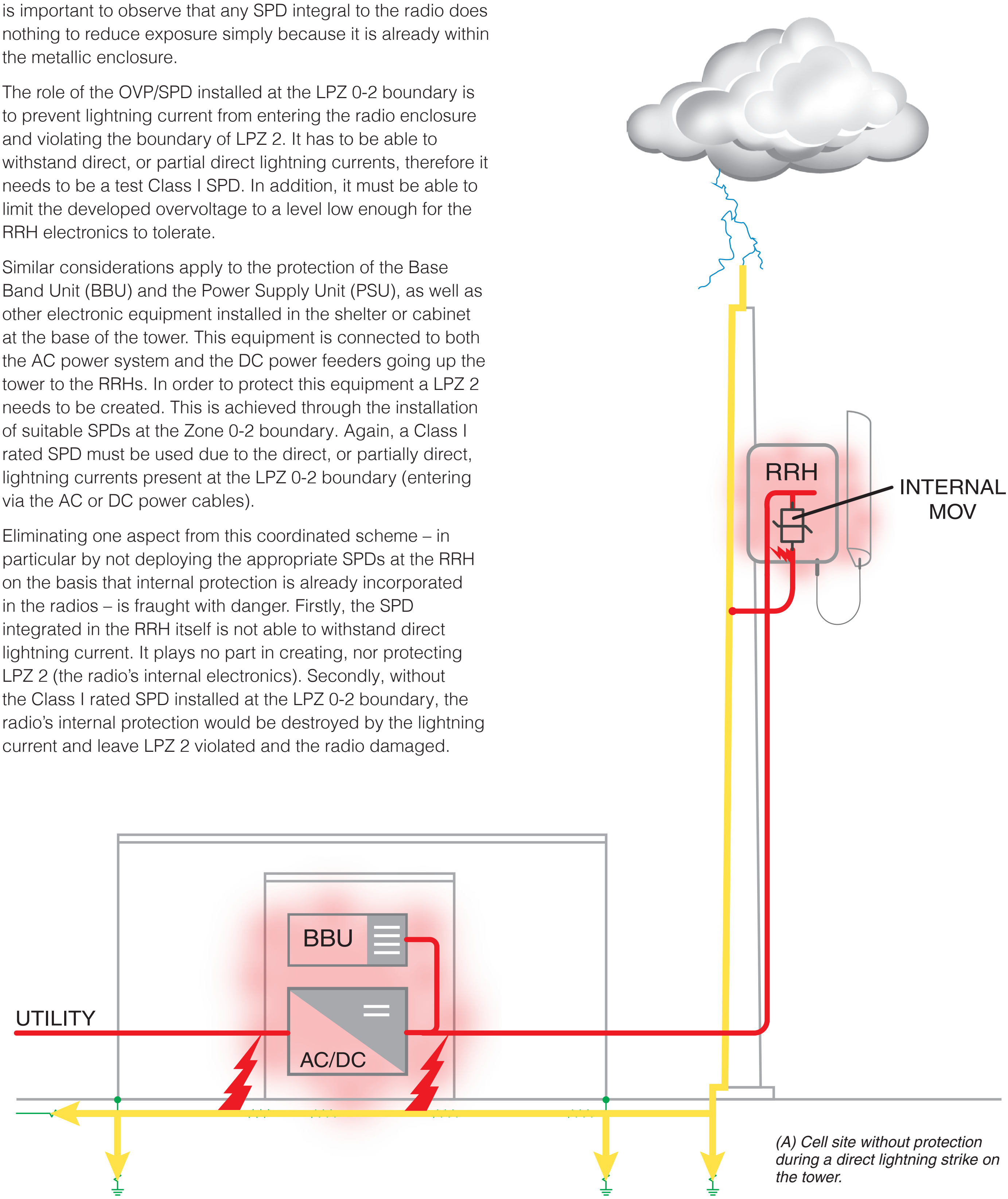
The role of the OVP/SPD installed at the LPZ 0-2 boundary is to prevent lightning current from entering the radio enclosure and violating the boundary of LPZ 2. It has to be able to withstand direct, or partial direct lightning currents, therefore it needs to be a test Class I SPD. In addition, it must be able to limit the developed overvoltage to a level low enough for the RRH electronics to tolerate.

Similar considerations apply to the protection of the Base Band Unit (BBU) and the Power Supply Unit (PSU), as well as other electronic equipment installed in the shelter or cabinet at the base of the tower. This equipment is connected to both the AC power system and the DC power feeders going up the tower to the RRHs. In order to protect this equipment a LPZ 2 needs to be created. This is achieved through the installation of suitable SPDs at the Zone 0-2 boundary. Again, a Class I rated SPD must be used due to the direct, or partially direct, lightning currents present at the LPZ 0-2 boundary (entering via the AC or DC power cables).

Eliminating one aspect from this coordinated scheme – in particular by not deploying the appropriate SPDs at the RRH on the basis that internal protection is already incorporated in the radios – is fraught with danger. Firstly, the SPD integrated in the RRH itself is not able to withstand direct lightning current. It plays no part in creating, nor protecting LPZ 2 (the radio's internal electronics). Secondly, without the Class I rated SPD installed at the LPZ 0-2 boundary, the radio's internal protection would be destroyed by the lightning current and leave LPZ 2 violated and the radio damaged.

Finally, without a very low voltage protection level provided by the SPD installed at LPZ 0-2 boundary, the radio's internal protection would not reduce the protection level low enough to ensure the radio's withstand capability is not exceeded, again leaving the radio damaged.

Figure 8 illustrates how the installed SPDs serve to protect the equipment during the lightning event.



(A) Cell site without protection during a direct lightning strike on the tower.

In practical terms, by not installing the appropriate SPDs, a significant portion of the total lightning current penetrates the RRH/BBU/PSU unit (making it effectively an LPZ 0 zone) and exposes its internal electronics to damage. This may also create a fire hazard by breaking down the internal insulation and arcing to chassis as the current tries to establish a path to true ground via the infrastructure's metal work. Either the overall lightning protection system is implemented as designed, or the complete system is rendered ineffective if selective elements are eliminated or not included.

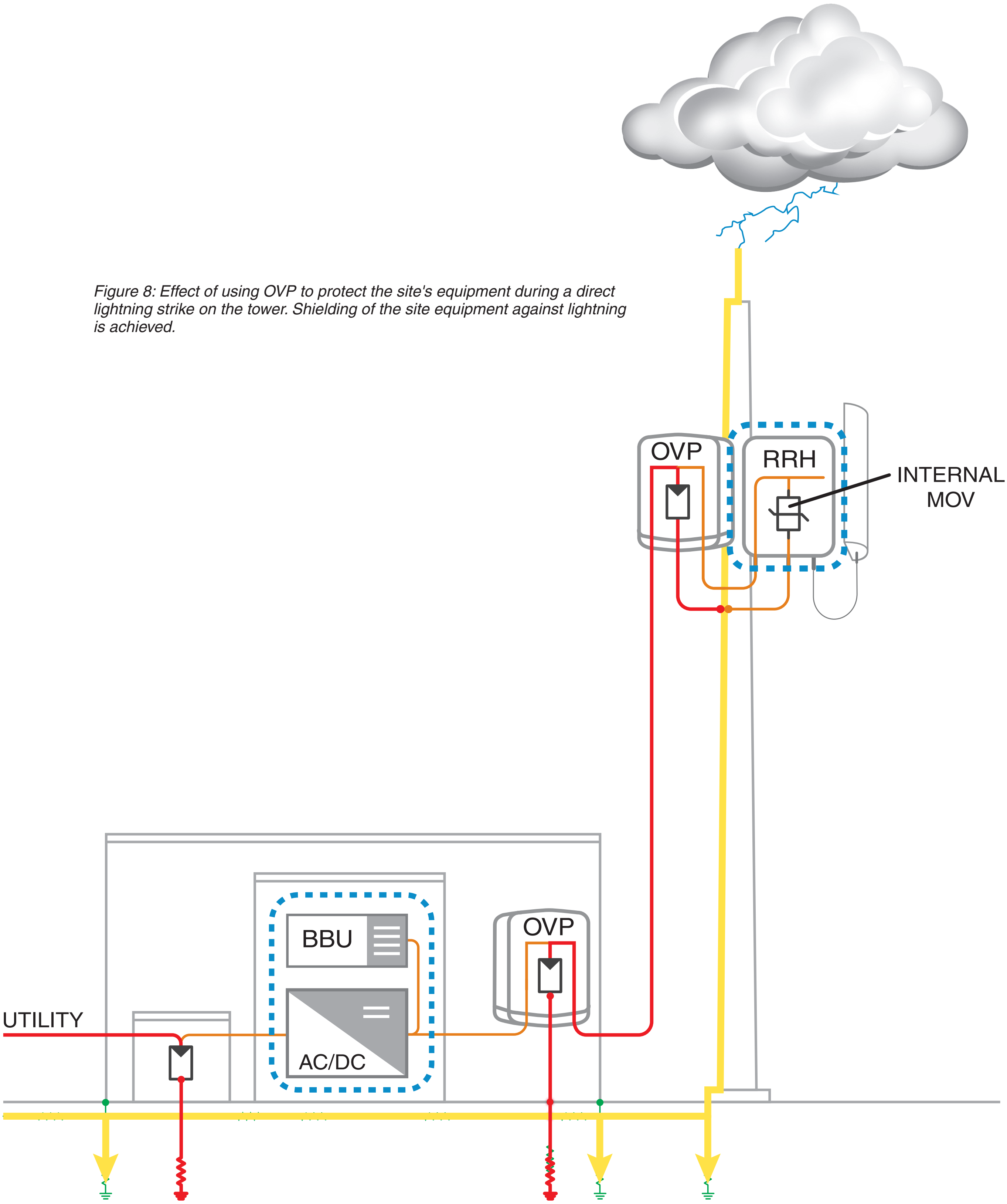


Figure 8: Effect of using OVP to protect the site's equipment during a direct lightning strike on the tower. Shielding of the site equipment against lightning is achieved.

6. Is protection required on rooftop locations even when surrounded by taller buildings?

Even when cellular sites are located on rooftop locations surrounded by taller buildings, they are at risk from the direct lightning strike. Figure 9 provides a number of photographs where it is evident that the tallest structure is not always the one to which the lightning downleader will attach.

Figure 9: Cases where lightning does not strike on the tallest building.

IEC 62306-4 deals with scenarios of both direct and nearby strikes, to both structures and current carrying conductors entering a facility. In the Standard, material is provided explaining the mechanism of inductive coupling onto loops formed by conductors within a building. It is interesting to note that significant current can flow in such conductors due to strikes which have not even struck the structure itself but are only in close vicinity to it.

Figure 10 depicts surge currents induced onto power feeders in a cellular installation due to a nearby strike.

In conclusion, for the reasons explained above, the protection of a cellular site installed on roof tops should not be compromised on the basis that adjacent taller structures will shield them from the effects of lightning.

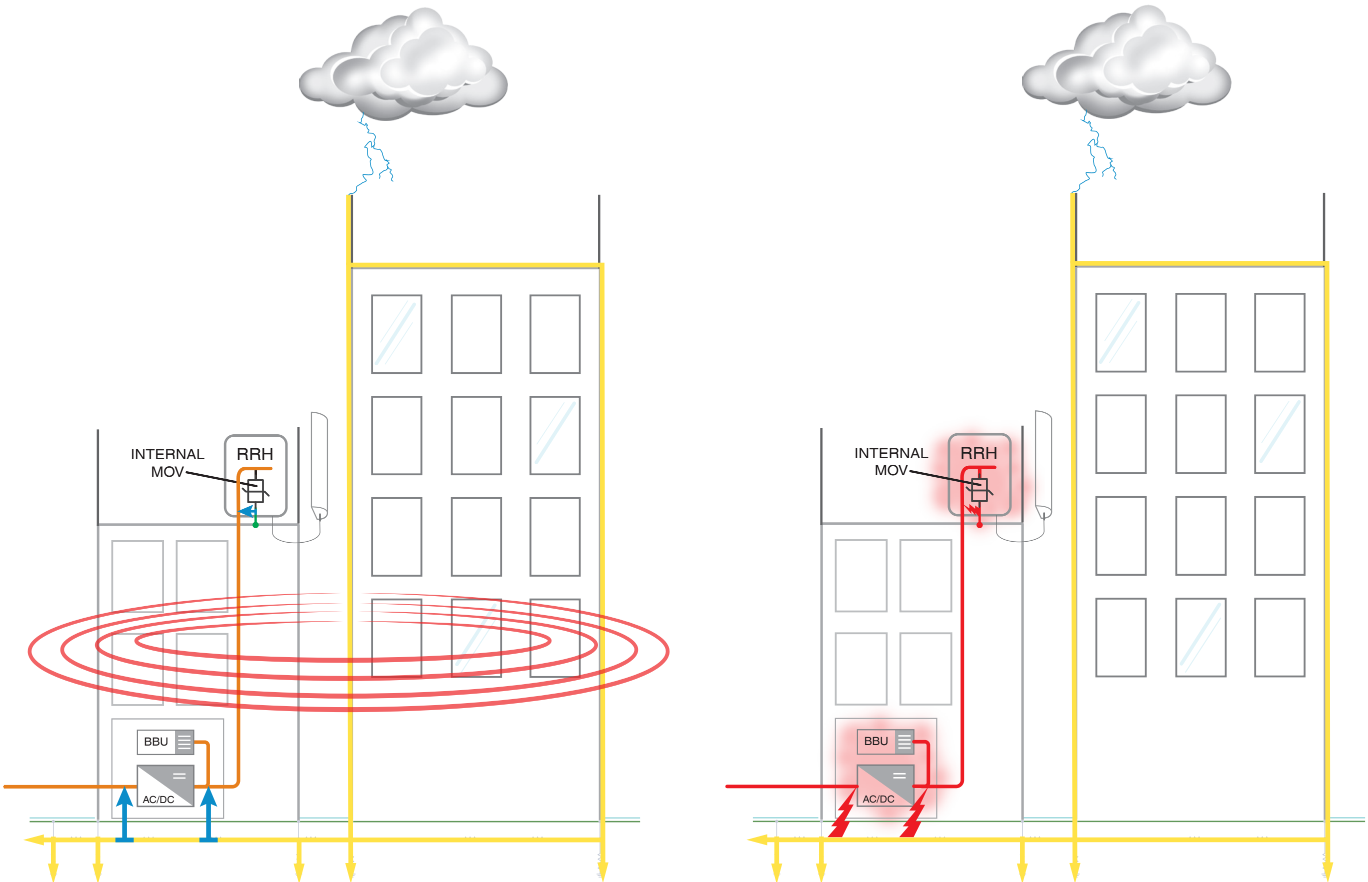


Figure 10: Induced surge currents due to a lightning strike to a taller structure close to a rooftop cellular installation.

7. Is external protection required even if radios incorporate this internally?

This has already been addressed in Section 5 where it has been shown that internal surge protection alone is not adequate to ensure the safe operation of electronics under lightning conditions.

Typically, the internal protection used in remote radio units comprises little more than a PCB mounted MOV and/or GDT of low surge energy capacity. This is primarily provided to allow the manufacturer to claim overvoltage protection, rather than to truly survive the conditions it will be exposed to, or to reduce the incident surge event to below the withstand level of the radio itself.

The IEC Standards on lightning protection describe four scenarios where protection measures are required. The most severe of these deals with protection against direct strikes to the structure (so called Scenario I). In cellular towers, where the RRHs are installed at the top of the towers, a Scenario I event can result in significant lightning current flowing from the tower-top to ground, even when a dedicated LP system with appropriate downconductor is installed. A portion of this current will use aspects of the radio's own wiring system, such as its low voltage DC power supply cabling, to reach ground. It may also use the internal MOV devices integal to the radio as a sort of equipotential bond to bypass currents on the DC cabling to chassis ground (the tower frame at the top).

Such internal protection to the radio is seldom rated to sustain the significant amount of energy involved in direct strikes. Indeed, the IEC standard 61643-11 developed the Class I test to evaluate an SPD intended for use in such Scenario I locations, where they may be expected to carry "direct or partial-direct lightning currents". The Class I test regimen involves use of the 10/350 μs waveform in evaluating an SPD's ability to safely divert these large currents. Most internal protection found in RRHs is only evaluated to test Class II, where the much lower energy 8/20 μs waveform is used.

In order for an SPD to be classified as Class I or Class II (or ideally both) the testing required by international standards like IEC 61643-11 is not limited to only subjecting the SPD to one impulse of a particular lightning current waveform. The Standard requires a lengthy testing regimen involving several impulses of different amplitudes and in a particular sequence, while measuring key parameters of the SPD that need to be kept within specified limits. In addition to surge impulsing, an SPD under evaluation for certification goes through a series of thermal, environmental and overload conditions since the objective of the standard is to simulate the lifetime cycle of the SPD under typical installation conditions and verify that it is able to maintain its performance throughout its lifetime. Therefore, even if an SPD claims a certain kA of lightning current performance, it should not be implied that such an SPD can be regarded as equivalent to a fully certified Class I SPD.

In most cases where surge protection is integrated in telecommunications equipment (normally this involves simply providing MOV components on the main PCB), these devices become one of the most common points of failure within the radio when under direct or indirect lightning exposure.

IEC 62305-4 deals with the protection of electrical and electronic equipment within structures from the effects of lightning. As explained in Section 5, the approach involves the creation of Lightning Protection Zones (LPZs). These zones are regions of reduced risk where the equipment within is protected. Measures used to create such zones include electromagnetic shielding (such as the metallic enclosure of a radio unit will provide to the internal circuitry), as well as the installation of SPDs at zone boundaries, which serves to reduce over voltages to below the withstand level of the equipment. The SPDs also provide an equipotential plane where voltage differentials are eliminated. The installation of an SPD within the boundary of the LPZ does not contribute to the protection provided by the LPZ.

8. What is the required surge rating of SPDs used in the protection of RRHs and BBUs?

The lightning withstand capability of the OVP should be selected based on the following criteria:

- It should provide effective protection during a typical lightning strike. The lightning current during a lightning strike can be as high as 200kA 10/350 but this does not mean that the SPD where it is installed will actually be exposed to such high levels in a typical cellular site configuration. The majority of the current will go to the ground through the tower's metal structure. The mean current associated with 50% of the C-G discharge, which is approximately 35kA 10/350.
- The expected lightning current that the SPD protecting the radio will conduct depends on the peak value of the direct lightning current, the site configuration, the power of the radios and can be anywhere between 5kA and 15kA. Acquired field experience over the past 10 years in hundreds of thousands tower top applications in North America, has confirmed the above values.
- Field experience with similar applications should also be reviewed when selecting appropriate withstand levels for the OVP (for example, SPDs used to protect wind turbine applications are usually rated 7.5kA to 25 kA 10/350.)
- The ability of any SPD to manage a certain level of lightning current is not enough on its own to secure an adequate protection level for the electronics (Radios and BBU's) at the site. What is far more important is for the SPD to be able to maintain the let through voltage at its ends at a low enough level. The equipment is directly exposed to the SPD's let through voltage and if this is too high (beyond its ability to withstand), it will simply fail.
- Most SPD manufacturers attempt to secure low let through voltage and low-level voltage exposure to the equipment through a series installation of a Class I SPD followed by a second, Class II SPD. The role of the first Class I SPD is to manage the energy carried by the direct lightning current and safely dissipate it to the grounding system. However, the let through voltage of such an SPD (typically a spark gap) is too high and if connected directly to the equipment, it will lead it to failure. The role of the Class II SPD is to reduce the let through voltage produced by the Class I SPD to a level acceptable to the equipment. However, this is in many cases, a questionable practice because the coordination of the two SPDs is very delicate and in practice can only be demonstrated in a lab environment where very specific current waveforms are employed. Field results including several cases of failure in direct lightning environments have shown that this claimed coordination does not work in practice and in many cases, the Class II SPD ends up failing and causing damage to the equipment as well.
- A technology available in the market since 2000 which combines the properties of both Class I and Class II SPDs in a monolithic block, known as ***Strikesorb***®, has been hugely successful in addressing these practical coordination challenges. Strikesorb can withstand lightning currents up to 25kA 10/350 and at the same time offer let through voltage levels of close to 100V therefore combining the benefits of both Class I and II SPDs without the drawbacks of coordination.

9. What protection measures against lightning are used in other applications?

The installation of surge protection on the AC side of cellular sites is already well established as good engineering practice and has been attributed to reliable and uninterrupted operation of such systems throughout North America. This same requirement is perhaps even more important with the move to mast-head RRHs with their long runs of low voltage DC power cabling from the base shelter PSU to the radio at the top of the tower. Such installations are particularly exposed to the effects of both direct and induced lightning effects.

This same high exposure also applies to other similar industries/applications, such as wind turbine generators. Given that such structures are very often installed on elevated ground to catch the wind – a little like telecommunications facilities need to maximize their line-of-sight for good communications - it is accepted engineering practice that all wind turbines incorporate overvoltage protection on both their power and data systems, irrespective of the isokeraunic lightning geography where they will be installed. Many European countries, such as Germany (whose average lightning density is the same as that of the US West Coast) have introduced legislation making lightning protection mandatory on all residential dwellings, in addition to industrial buildings, cellular sites etc. This trend clearly notes the growing recognition that, as our electronics infrastructures become more complex and critical to all aspects of our every-day lives, so too does it vulnerability to atmospheric electricity and overvoltage events.

10. Conclusions

This white paper has sought to address a number of the more topical questions which are often posed concerning the need for surge protection on telecommunications sites.

It has reinforced the need for effective overvoltage protection for both the base shelter equipment (PSU/BBU etc) as well as the remote radio heads (RRH). It has introduced the reader to the principles adopted in the IEC standards on both lightning protection (IEC 62305 series) as well as surge protection (IEC 61643 series). In particular, the zone of protection method has been illustrated, where the the lightning threat level is progressively reduced via the use of LPS, SPDs and EMP shielding, to the point where sensitive electronic systems can be protected even in the presence of a direct lightning discharge.

It has sought to explain why isokeraunic maps of thunderday activity throughout the USA are becoming less reliable as a determination whether protection should be installed or not, due to changing weather patterns and the growing frequency of abnormal storm activity, significantly distorting the annual average.

It has also explained that the induced effects of nearby lightning discharges can be just as catastrophic to sensitive electronics as the all too evident direct strike to the tower itself. This is largely due to the fact that the magnetic impulse from an indirect strike can couple significant energy onto the wiring infrastructure of a remote site. This point is highlighted when considering whether protection is needed when a particular site is surrounded by higher structures.

Finally the paper has concluded by examining standard industry practice pertaining to the implementation of surge protection in other applications and locations throughout the world, in an attempt to offer some insight into how other industries adopt best practice when seeking to mitigate the effects of this awesome event of nature.

11. References

1. NFPA 780-2014. *Standard for the Installation of Lightning Protection Systems*; 2014 Edition.
2. D. M. Kingfield, K. M. Calhoun, K. M. de Beurs. *Antenna structures and cloud-to-ground lightning location;* 1995–2015. Geophysical Research Letters: 44 (10) (2017), 5203–5212.
3. IEC 62305-2. http://www.iec.ch/. Accessed: 2018-04-25.
4. R. L. Holle, K. L. Cumins, W. A. Brooks. *Seasonal, monthly, and weekly distributions of NLDN and GLD 360 cloud-to-ground lightning*. Monthly Weather Review: 144(2016), 2855–2870.
5. BBC News. http://www.bbc.com/news/world-asia-india-43905726.
6. Viasala. https://www.vaisala.com/en. Accessed: 2018-04-25.
7. Blitzortung.org. http://en.blitzortung.org. Accessed: 2018-04-25.
8. A. F. Prein, C. Liu, K. Ikeda, S. B. Trier, R. M. Rasmussen, G. J. Holland, M. P. Clark. *Increased rainfall volume from future convective storms in the us*. Nature Climate Change: 7 (2017), 880–884.
9. H. E. Brooks. *Severe thunderstorms and climate change*. Atmospheric Research: 123 (2013), 129–138.
10. R. E. Orville, G. R. Huffines, W. R. Burrows, K. L. Cummins. *The north American lightning detection network (NALDN)—analysis of flash data*; 2001–09. Monthly Weather Review: 139 (2011), 1305–1322.
11. Lightningmaps.org. https://www.lightningmaps.org. Accessed: 2018-04-25.
12. D. M. Romps, J. T. Seeley, V. David, M. John. *Projected increase in lightning strikes in the united states due to global warming*. Science: 346 (6211) (2014), 851–853.

Raycap

www.raycap.com

G09-00-118 181004