

Research on Equipotential Earthing Optimization Bonding in Radio Base Station

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Abstract—Earthing is the foundation of lightning protection of the RBS (radio base station), providing a way for discharging the lightning current. Equipotential bonding can protect equipment from lightning attack, providing a potential reference point for all equipment. There are two methods for the equipotential bonding. The first is the constant bonding, that is, equipment are grounded directly through earthing wire and the other is the instant bonding which should be used for the earthing through SPD (Surge Protective Devices). The paper will discuss the implementation problems on equipotential bonding of the RBSs.

Keywords—Earthing, Equipotential, Optimization, Bonding

I. SUMMARY

For the lightning protection of RBS, the problem of the equipotential bonding has always been talking about. The earthing of RBS is necessary and foundational. Till now, many technicians have only focused on the connection of devices which can be earthed directly; Some people mistakenly think SPD is not useful for they ignore an important issue: how to implement connection for many systems, such as power supply, signal ports that can not be earthed directly in the RBS.

II. CONSTANT (INSTANT) BONDING AND EQUIPOTENTIAL BONDING

Thunderstorm and lightning has always been a research subject around the world; people have been constantly exploring the formation of lightning and the characteristics of lightning strike, and the understanding level of thunderstorm and lightning has been raised continuously, but some concepts and understanding of lightning have been controversial for a long time; for example, there are different opinions on the equipotential bonding. For many technicians, their understanding of equipotential bonding is only limited to the steady equipotential bonding which is that the devices and different metal structures are directly connected by the earthing wire. They believe that the problem of potential difference between the telecommunication system and the equipment can be solved as long as the steady equipotential bonding can be handled properly. However, the equipment is constantly damaged when lightning occurs; the damage is caused by this wrong understanding. As a matter of fact,

quipotential bonding is classified into two categories: one is the steady equipotential generated by using the earthing wire to directly connect; the other is to connect through the SPD which is disconnected at other times, and when there is over-voltage from thunder and lightning, the SPD is converted to lower the resistance to let lightning current discharge through the earthing system. The concept of potential for the first category is: no matter how high the potential of the potential plane of equipment housing is, (no matter it is at the top or the bottom of the building), it is acceptable as long as all equipment and facilities in the equipment housing are at the same potential or the potential difference that is not enough to cause equipment damage. Reference point is very important; the earthing wire does not have to be connected with the ground grid from downstairs and it is better to set the reference point on the floor where the equipment housing is, not necessarily to set the ground-buried earthing body of the building as the reference point. As for the second category, if there is no outgoing power or signal line, the potential in the equipment housing is equal; if there are power or signal lines, the problem of importing low potential occurs. To solve the problem, it only needs to install SPD protection at the ports to realize the equipotential bonding. Power lines can not be directly earthed, nor can the signal lines due to signal transmission, so the power and the signal lines are earthed through the SPDs. SPD equipotential bonding belongs to the instant bonding, while the constant equipotential bonding of RBS can only solve the problem of those metal structures able to be earthed directly. The equipotential bonding of power lines, signal lines and feeders unable to be directly earthed must add SPD on the lines in a parallel manner to discharge lightning current when the lightning occurs.

III. ANALYSIS ON THE REASON OF HIGH DAMAGE RATE OF RBS EQUIPMENT BY LIGHTNING STRIKE

Equipments and devices damaged by lightning strike in RBS include: power supply equipment accounting for 90% (transformers, power distribution boxes, regulators, rectifier modules, air-conditioning boards, lighting systems), signal equipment accounting for 10% (core devices of GSM or CDMA equipment: CPUs, the user boards, monitoring systems, sensors, fire control panels, small microwave instrument)[1]. These damaged equipment and devices are all

connected by the power and signal lines in the RBS. The rise of ground potential when lightning happens or the potential difference between different equipment due to surge voltage caused by lightning electromagnetic fields leads to the breakdown of equipment insulation and internal components, which finally damages equipment.

IV. EQUIPOTENTIAL BONDING OF RBS

A. Mesh connection and star connection

There are two equipotential bonding approaches in RBS: one is mesh connection configuration; the other is star connection configuration.

It is best to use the mesh connection for the equipment housing of RBS, because huge star connection adopted in the housing is apt to cause relatively great potential difference between different equipment which brings about the damage. However, the use of mesh connection can significantly reduce the above problem. Ring earthing wires can be set along cabling racks and walls in the housing for the mesh connection. The material of the ring earthing wires is copper of 30 mm×3mm (or flat steel of 40mm × 4mm). The ring earthing wires are fixed on the walls with mounting clips. If ring earthing wires are close to the cabling racks, they can also be fixed on the cabling racks with the clips. All equipment and devices in the housing should be reliably connected with the nearest ring earthing wires with copper wires of 16mm² (these equipment and devices include AC power distribution box, switching power supply, GSM equipment, SDH equipment, DDF, environmental monitoring equipment, cabling rack, metal door and window and so on).

According to the placement of equipment in the housing and possible expansion of equipment, the ring earthing wires can be arranged to be the form of “日” or “目” shape. The ring earthing wires should be connected with the nearest ground grid in the manner of multi-point by using of galvanized flat steel or multi-strand copper wires with the cross-sectional area of no less than 95 square millimeters. In terms of public buildings or rented houses, the reinforced steel bars should be taken out from the walls to be reliably connected with the ring earthing wires. All connections need to be welded and conducted anti-rust treatment.

When employing the star connection, the main earthing bar of RBS should be near the distribution box and the first-level power SPD; earthing main wires of switching power supply and other equipment should be all connected with the main earthing bar. If the equipment housing is far away from the main earthing bar, double-leveled bar(s) can be used. In this case, the earthing wires of the first-level power SPD, AC power distribution box and optical fiber strengthening core and its metal protection layer should be earthed through the main earthing bar; other equipment in the station should be earthed through the second level bar. These two earthing bars need to be linked with multi-strand copper wires with a cross-sectional area of 70 mm².

B. Comparative Analysis on the Two Equipotential Bonding Approaches

1) *Disadvantages of Typical Star Earthing.* The earthing of equipment in housing in china is shown in Figure 1 (a) [equivalent diagram: Figure 1 (b)], which is a typical star earthing. This kind of earthing is widely used in many RBSs. However, because the equipment earthing wire is too long (in general, up to 5 to 10 meters), while discharging energy of lightning, a great potential difference may be evoked on the earthing wires, which may sometimes lead to the equipment damage. In addition, as the equipment earthing wire is too long, the ring area made up of the earthing wires of a number of equipment and transmission lines is too large, and the electromagnetic induced over-voltage generated by space electromagnetic field when lightning becomes another important cause for the equipment damage.

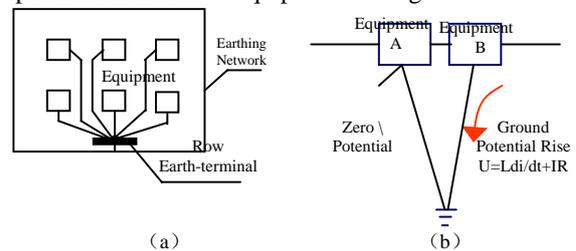


Figure 1. Star Earthing

2) *Advantages of Mesh Connection.* The mesh connection can eliminate the hidden danger of damaging equipment in housing as a result of the use of a large star connection that can easily generate greater potential differences between equipment. The star earthing will be modified in the way shown in Figure 2 (a) [Equivalent diagram: Figure (b)] below, i.e. changing from the large star connection into the mesh connection.

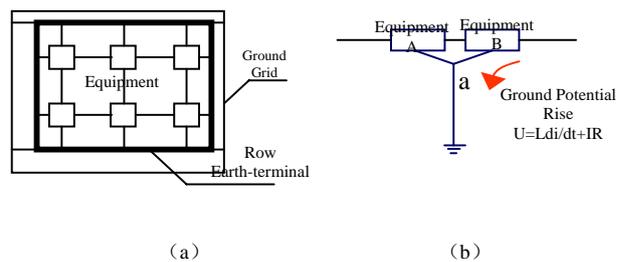


Figure 2. Mesh Connection

The potential difference can be calculated according to the following formula:

$$U=Ldi/dt+IR \quad (1)$$

Where: L is the inductance of the bonding wire between the equipment and the equipotential bonding point, and R is the resistance of this bonding wire. Suppose the length of the wire is 1 m and the lightning current is 20kA (8/20us), then the voltage drop on the wire is 3.6kV/m. If the equipotential bonding point is moved to Point 'a' (The distance between 'a'

and Equipment B is 0.5m, and the distance between 'a' and PE is 4.5m), then potential difference between Equipment A and B drops to 1.8kV, only one-tenth of the original potential difference.

V. BASIC CONNECTION STRUCTURE

A. *Telecommunication Switching Power Supply Must Be Linked to the First Level Power SPD in the Way of Equipotential Bonding.*

Equipotential bonding of equipment in RBS housing, a crucial aspect is always ignored, which refers to the equipotential bonding between switching power supply and the power supply first level SPD. In general, as the current the switching power supply got from the AC distribution box is of 3-phase and 4-wire, and the inter-stage matching problem exists between the first and the second stage lightning arresters, the first stage lightning arrester(s) must be always set close to the distribution box and main earthing reference point must be closely set.

B. *Establishment of Earthing Reference Point*

Whether the earthing reference point for RBS is chosen properly is a significant aspect for evaluating the equipotential bonding. The domestic RBSs generally use mesh-star approach, while foreign RBSs generally adopt the mesh earthing approach (its advantage is to reduce potential difference that may occur on the earthing wires). To choose correctly a reference point for mesh- star earthing is very important; if the design is ill-considered, the lightning strike will result in a large potential difference on the earthing wire, which is sometimes enough to damage the equipment.

C. *Relation between the Establishment of Earthing Bar and the Earthing Please see last page of this document for AN EXAMPLE of a 2-COLUMN Figure.*

As the RBSs room is small in size, only one earthing bar is used to provide the reference point for the switching power supply, transceiver, transmission equipment, environmental monitoring device and the main distribution box interiorly. For the earthing of equipment, the length of ground lead may not greatly affect on the equipment; nevertheless, in terms of lightning over-voltage protection, the length of SPD ground lead is related to whether the SPDs installed in the RBS can play the role of protection and especially to whether the RBS is struck by lightning again (SPD can not 100% solve the problem of lightning strike.)

D. *Earthing Wires of the First Stage SPD of the Main Distribution Box*

We are often told by the maintainers of RBSs that equipment is still damaged by lightning even the RBS has installed the first-level SPD. Apparently, correctly choosing SPD is a very important issue. To decide the type of SPD is based on the division of thunderstorm region, the category of telecommunications bureaus (stations), the geographical environment of RBS, the building form, the way of power supply and voltage stability of locality power supply, as well as the matching of the SPDs. Not all SPDs can solve the

lightning striking problem; we must solve such problems as SPD operating voltage and maximum discharge current; for example. SPD with 80kA per line is always adopted in thunderous regions; however, SPD offered by some vendors is the sum of SPD phases (although it reaches 80kA or 80kA / each phase as well), possesses an inadequate capacity of current discharge for the first-grade protection of the power supply. If passing off small-capacity SPDs as large ones, or inferior ones as superior ones (the first-class protector) (Related problems will be specially discussed), it is more impossible for SPD to play the role of protection.

Yet, what we discuss here is even we use well-known brand SPD with very good indexes, RBSs are still struck by lightning. In this case, it is necessary to look for other reasons of lightning strike, such as earthing. For example, one important factor of lightning strike is the length of ground lead of SPD; the first stage of SPD is generally installed at the entrance of distribution lines, but the main earth-terminal is often on the cabling rack far away from the entrance, we have to connect the first stage of SPD to the main earth-terminal with a ground line of 2~6 meters long; The excessively long ground line results in a large residual voltage, which makes SPD unable to protect any equipment. Moreover, in most cases, in order to facilitate the construction of the ground lead, the multi-strand copper wires of 16mm² are always used, and inductance of the wires itself will be enough to make SPD residual voltage rise to the situation that can not be tolerated[2].

1) *Ground Lead of SPD within Switching Power Supply.* The earthing of SPD within switching power supply, if to see the issue separately, installation location of SPD in the switching power supply is according to the characteristics of equipment decided by designers; the ground lead may be shorter in the devices. However, if some isolated equipment is integrated into a system and consider it with concept of systematism and integrity, the problem of isolated, single equipment exposes. For example, Earth-terminal and ground lead of RBS is usually fixed on top of cabling rack, Then for installation location of SPD used in switching power supply, the best option is to naturally select the product on top of which the SPD is designed. If choose product whose SPD is at the bottom of switching power supply, then it is a failure and mistake to lightning protection design, because the residual voltage value is as high as 1000V if the length of SPD ground lead 1m. When deal with access network equipment and mobile communication RBS co-site, writer finds if the SPD is installed under the switching power supply which needs ground lead of 2 meters to connect with cabling rack, (In the communication building, if there are trenches, installing SPD under the switching power supply way is the best way.), then whether the SPD is workable is unknown. Therefore manufacturers should offer clients different design options and equipment with systematism and integrity according to different types of RBSs.

2) *Feeder Distribution SPD and Ground Leads of Other equipment.* According to specification requirements, the

earthing of feeder distribution SPD is requested to connect with outdoor earthing bar at the entrance of feeder distribution. This is based on principle of EMC which follows three elements of shielding, filtering, earthing, the same as resolving the interference channel to solve the import of lightning current. Keep lightning current out of RBS rooms with minimal impact to the equipment.

In addition, earthing of DDF board of 2Mb/S connector installed in base station room as well as environmental monitoring, DC distribution plate also needs to consider.

E. DC Protection Device Is the Internal Switching Power Supply Supplementary Equipotential in Thunderstorm Region

The main impact to equipment from the earth terminal is transient potential rise, DC power supply of RBS generally involves two categories: 24V (DC negative earthing), and -48V (DC positive earthing), both of them need to be earthed.

Lightning discharging through ground grid will generate transient potential rise. This makes large transient potential difference between positive and negative DC which results in equipment damage of sensitive parts (rectifier modules and transceivers, etc.). Sometimes potential rise is the front end (switching power supply DC output port) to damage equipment, or may also be from the back end (electrical equipment, such as GSM DC input port) to damage equipment, so both ends of DC power supply need to install lightning protection devices to form an instant equipotential bonding between positive, negative of DC power supply and ground. Prevent equipment damages caused potential strikes which come from ground potential rise.

In the past analysis of impact on the resistive coupling from ground potential rise is only based on theory. Statistics of the practical application, on-site RBSs, DC-SPD of switching power supply damage caused by lightning is very rare.



Figure 3. The damaged DC SPD

The Figure3 shows one case of the damaged DC SPDs on the switching power supply by lightning. But the DC SPD damaged by lightning strike, is the situation of damaged SPD by lightning strike installed on DC end of switching power supply, the energy created by ground potential rise is still quite considerable. Therefore, it is not a problem to install DC switching power supply SPD, in thunderstorm days and

strong lightning region, especially for RBS with steel tower, DC SPD must be installed at the DC end of switching power supply to protect.

F. The Treatment of Metal Components Earthing in Fiber Optic Cable

Fiber optic cable into the RBS whose enhance core of internal metal components and metal protection layer inside PVC plastic to be earthed is very important. There are two earthing approaches for fiber optic cable[3], one is that the metal component of fiber optic cable directly earthed, the other is disconnected metal component of fiber optic cable with ground. The RBS adopts the former.

Since fiber optic cable is always introduced in the RBS room in an overhead manner, the long-distance aerial cable may introduce lightning. Steel strand of suspension fiber optic cable can discharge lightning current by adding insulator which disconnect metal structure with ground or can discharge lightning current directly by connecting with ground grid of RBS. But the steel core and metal protection layer can be earthed as long as the fiber optic cable enters into the RBS. If there is cable connector box, steel core and metal protection layer can be earthed in connector box, then diverted to the optical or composite cabinet. If earthing of cable steel core and metal protection layer is bad, the worst thing is discharge occurs near fiber optic cable connector box. If the cable connects with composite cabinet directly after entering RBS, the steel core of cable and metal protection layer should be connected to a dedicated terminal with multi-strand copper wire of no less than 16 mm and earth in RBS through first level earth terminal.

Steel core of cable is easy to earth, but metal protection layer is often lack of attention with bad or no earthing. This will generate potential difference between steel core of cable and metal protection layer. Affected by the lightning, metal protection layer will discharge to earth terminal of steel core of cable. Under the effect of lightning, arc discharge may discharge to earth terminal or even worse, results in burning the outer layer of plastic fiber optic cable. There are many cases about the burning of outer layer of plastic fiber optic cable; it can lead to serious consequence.

VI. HANDLING PRINCIPLES FOR ANTENNA FEEDER EARTHING POINTREFERENCES

Antenna feeders of RBS are under the protection of lightning rods; according to the lightning protection zone concept, the direct lightning can't strike the antenna feeder directly. In order to realize equipotential bonding and proximity earthing, tens of meters of feeders and metal outer sheath of coaxial cables are required to be connected to the ground at the antenna, the point just separating from the tower and the inlet to the equipment room respectively; if the antenna feeder and other coaxial cables are longer than 60 m, it is advisable to add an extra earthing point at the middle part of the tower; both ends of outdoor cabling racks should be connected to the grounding grid as well.

According to the principle of electromagnetic compatibility, the antenna feeder should be connected to the ground bar at the outside of the inlet to the equipment room.

As for the tower built on the equipment room, under-tower earthing point of the antenna feeder is also very important.

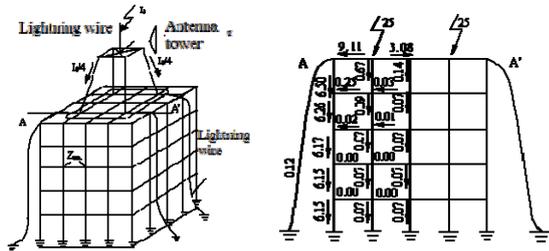


Figure 4. Lightning current distribution model

It can be seen from the distribution model of the lightning current that if the lightning striking at the lightning rod, 95% of the lightning surge current flows through the columns and walls of the building, as shown in Figure 4. Moreover, nearly all lightning current that strikes the building is concentrated on the external walls; the current through the middle columns only accounts for several percentage. Nearly all the lightning current inside the building flows along the vertical columns with little current flows horizontally except for the roof. For the RBS with nearby tower, the lightning current through the down conductor accounts for just a small percentage, the electromagnetic field induced current of antenna feeder system protected by the tower is even smaller.

Calculation demonstrates that in the case the lightning current of the direct lightning is 100 kA, if lightning current that flows through 4 square-tower steel structures is distributed well, current value of each tower leg is 25 kA; therefore, the current on the antenna feeder induced by the lightning electromagnetic field is no more than 1 kA. Through the calculation for tubular towers, triangular towers and square-towers mentioned in Section 4.5, we know that the transverse voltage scope of feeder cable is just in the range 0.006~0.050 kV.

In terms of the tower erected on the RBS room, if the under-tower earthing point of the antenna feeder is not directly on the grounding grid, but on one corner of the tower body, the distribution of lightning current can be quite different. Lightning current that originally flows through the tower body and columns of the building into the earth with the value of 25 kA per tower is divided into two channels: one is to the earth through the columns of the building, and the other is to the earth in the form of current that is no more than 1 kA induced by the lightning electromagnetic

field on the feeder and lightning current that flows into the earth through the tower body, tower corners to feeder, equipment enclosures and earthing lines; in this case, the current will change into thousands of amperes (even higher than 10 kA), that is, the channels and levels that the lightning current flows into the equipment room is increased. Antenna feeder earthing lines formerly connected to the tower corners are reconnected to the ground grids directly, as shown Figure5.

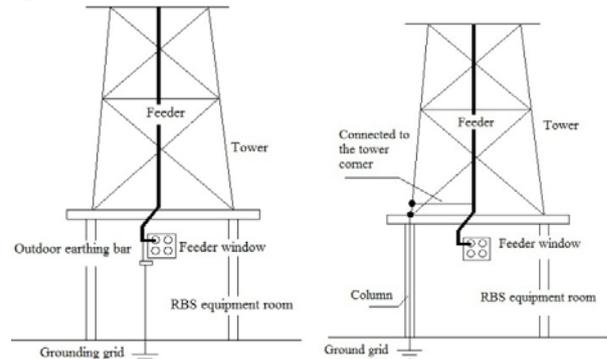


Figure 5. Tower built on RBS

VII. CONCLUSION

Constant and instant earthing of equipotential bonding are two different concepts. Generally speaking, constant earthing can only eliminate the potential difference between devices, while the instant earthing is more important. As the power supply, signal line are related to the output of high potential and input of low potential, therefore this damage is worse when lightning occurs. To ignore the protection for SPD of these terminals can result in great RBS damages when lightning occurs. Of course, lightning protection for RBS is a holistic and integrated program; lack of any step may lead to serious consequences.

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