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PROTECTION MEASURES FOR RADIO BASE STATIONS SITED ON POWER LINE TOWERS

Joint Working Group
C4.2.02

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(This is a condensed version of the ITU-T Recommendation K.57 with the same title)

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sited on power line towers

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Abstract

Locating radio base station antennas in power line towers is mainly of interest in rural areas, where there are no tall buildings for the antennas to be installed. In order to get a comprehensive view for the use of power line towers for RBS in different countries a common questionnaire has been made up commonly by CIGRÉ and ITU. The Study Group 5 of ITU-T has developed the Recommendation K.57 in close co-operation with the CIGRE WG C4.2.02 (formerly WG 36.02) on the bases of the replies received and the considerations of the particular electromagnetic environment affecting an RBS mounted on power line tower.

The Recommendation K.57 specifies measures to be taken with respect to safety and risk of damage to equipment through earth potential rise, when power line towers are used for locating radio base stations. It also considers the special lightning protection scheme, which is needed for this type of installation. This is of special concern, when power is fed from the low voltage network, which is the most common situation. Different feeding options are described.

The design of the protection of the supply circuit is covering the following areas:

- Identification of the tower potential rise due to earth fault, which is the key parameter for the required power frequency isolation level
- Characterization of the EPR and the control of the touch and step voltages by potential grading earth electrodes (PGE)
- Guide on the design of the protection schemes against the simultaneous stresses due to EPR and lightning surges.

The Recommendation K.57 (October 2003, Geneva) can be ordered from the Electronic Bookshop of ITU, on CD-ROM, on paper or on-line through the following website: *http://www.itu.int/publications/main_publ/itut.html*.

Keywords: LV supply protection, RBS feeding, RBS protection, Tower EPR

Abbreviations

EPR	Earth Potential Rise
T-EPR	Tower earthing potential rise
Z-EPR	Zone of the earth potential rise
RBS	Radio Base Station
HV	(High Voltage), Voltage levels exceeding 100 kV a.c.
MV	(Medium Voltage), Voltage levels lying between LV and HV
LV	(Low Voltage), Voltage levels not exceeding 1 kV a.c.
MOV	Metal Oxide Varistor
SPD	Surge Protective Device
PGE	Potential Grading Earth is an electrode system laid at small depth around the equipment cabinet(s).

1. Particularities of RBS on power line tower

At every power line tower with a radio base antenna, there is a cabinet located near the tower or between the legs sometimes elevated, if possible (see Figure 1).

Figure 1: RBS antenna (upper part of the figure) and the elevated cabinet

The location of the equipment cabinet is not a safety issue, but rather a question of accessibility to the tower and/or the ownership of the land occupied by the cabinet. This cabinet is hosting equipment for transmitting and receiving and has cable connections for power feeding and occasionally for signal transmission as well. There is a transformer cabinet for power supply in close proximity to the equipment cabinet or in a dedicated part of the cabinet. The antenna may be mounted below or above the phase conductors or even above the overhead earth wire(s), if any.

There are two phenomena that have to be considered simultaneously:

- When a single earth fault on a power line of a network with directly earthed neutral or a double earth fault on power line(s) of a network with non-directly earthed neutral occurs, a large EPR will appear at the tower, maybe tens of kVs. This problem is treated by isolating that part of the RBS equipment, which has external metallic connection, against its cabinet and equipment, which is bonded to the tower.
- Lightning hitting the tower. This problem is handled by bonding the above mentioned parts of the RBS equipment through suitable SPDs in order not to jeopardize the isolation for EPR.

2. Tower earthing potential rise

The EPR, as a general term, involves both the T-EPR and the Z-EPR. The tower earthing potential rise (T-EPR) is the potential of the earthing (footing) of tower with respect to the remote earth occurring during earth fault.

The amplitude of the T-EPR depends on a number of different factors such as

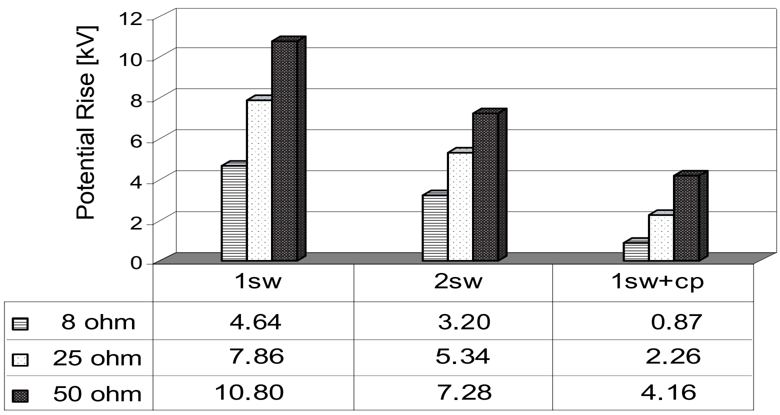
- earth fault current amplitude
- the earth resistance (average) of the tower
- aerial and underground earth wires, if applied
- the span between the towers
- distance to the feeding power stations.

The last factor has of secondary importance.

When the power line is equipped with aerial or underground earth wires, the significant portion of the fault current returns through these wires and only a fraction of the earth fault current flow through the tower footing. The T-EPR can be characterized by the product of that fraction ($3I_{0E}$) of the zero sequence component of the earth fault current ($3I_0$) that is passing through the tower footing, and the earthing resistance (R) of the tower, i.e. $3I_{0E}R$. The T-EPR values calculated by the multiconductor line simulation technique [1] are shown in Figure 2. These are given for different parameters assuming an average span of 333 m. The so-called base tower earth potential rise (T-EPR) values are plotted in Table 1 as per 10 kA, which is the total earth fault current ($3I_0$). The correction factors for the EPR due to span smaller or lower that 333 m are plotted in Table 2. The T-EPR is practically not affected by the span in case of power line equipped with counterpoise.

By the use of U_b base T-EPR values the following two kinds of design values can be determined:

1. The required isolation voltage U_{is} for a given earth fault current can be de-



Substation earthing at line ends: *0.1 Ω / 0.1 Ω*
Fault location: *at the middle of the line (L/2 = 30 km)*
Earth current at the faulty point: *1x10 kA*
Average span: *333 m*
sw: *Shield wire*, cp: *Counter-poise*

Figure 2: Potential raise of the faulty tower for different tower earthing resistances and shield wire / counterpoise options

Table 1: Base tower earth potential rise (T-EPR), U_b values for isolation level co-ordination, [kV/10 kA]

Earthing resistance [ohm]	Shield wire configuration		
	1 sw	2 sw	1 sw + cp
8	4.663	3.237	0.872
25	8.208	5.589	2.290
50	11.41	7.432	4.316

Average span: *333 m*
sw: *Shield wire*
cp: *Counter-poise*

Table 2: Correction factors for the tower potential rise of lines with different span (Base: the tower voltage for span of 333 m)

Span	*Tower earthing resistance*		
[m]	*8 ohm*	*25 ohm*	*50 ohm*
200	0.77	0.77	0.77
333	1.00	1.00	1.00
500	1.22	1.22	1.22

Line configuration: *400 kV, 2 shield wires*
Line length: *L = 60 km*
Fault location: *L/2 = 30 km*
Substation earthing resistances: *0.1 ohm / 0.1 ohm*

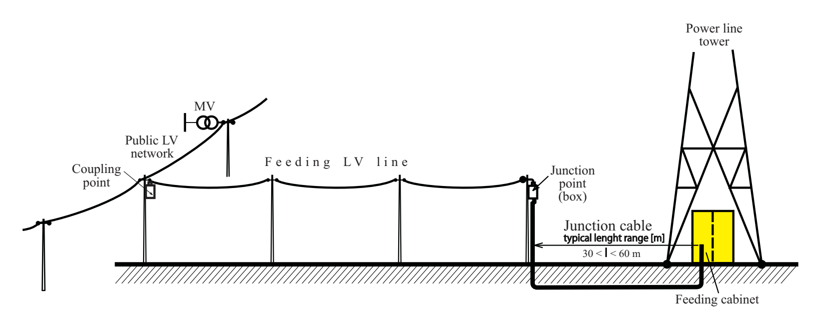


Figure 3: Typical arrangement of LV feeding

termined by the following expression:

$$U_{is} = U_b \frac{I_{ef}}{10} \quad [kV]$$

2. The permissible phase-to-earth fault current I_{ef} corresponding to different pre-defined isolation voltage levels (U_{is}) can be determined by the following expression:

$$I_{ef} = 10 \frac{U_{is}}{U_b} \quad [kA]$$

where:

U_b is the base voltage, taken from Table 1, corresponds to the average earthing resistance and shield wire configuration of the line under study, and

U_{is} is the pre-defined isolation voltage level of the power feeding facilities (isolating transformer, cabling).

From an engineering design point of view, it can be assumed that a series of isolation transformers are manufactured with given isolation voltage levels. In this case, the permissible earth faults, classified according to the isolation levels, can be identified for the average earthing resistance and shield wire configuration of the line under study by using the above expression for I_{ef}. The permissible earth fault current values are Tabled in K.57 for isolation voltage levels of 10 kV, 15 kV, 20 kV and 50 kV.

3. Zone of the earth potential rise

The zone of the earth potential rise (Z-EPR) is that area, surrounding the tower of the power line, where earth potential with respect to the remote earth occurs in case of single phase to earth fault, or in case of non-directly earthed network, double earth fault. This potential falls more or less rapidly in the earth ("potential funnel") as the distance from the tower footing increases. The magnitude and the way of decrease of the potential depends on the following factors:

- magnitude of the T-EPR causing the Z-EPR
- geometry (size and structure) of the earthing system
- soil characteristic (geological nature, stratification etc.).

The potential funnel is investigated by the powerful CDEGS software, which solves the electromagnetic field problem of the modelled electrode system embedded in homogeneous earth with a given specific soil resistivity. (The CDEGS software can model stratified earth structure as well.) The results of the investigation have been used according to the following sections.

3.1 Estimation of the minimum length of junction cable

That section of the feeding line, which lays in the Z-EPR, shall have increased insulation strength with respect to the earth. This section between feeding cabinet at the tower and the junction box (see Figure 3) is referred as junction cable. Its minimum length is determined accordingly to the followings.

It is well known from the technical literature that the Z-EPR can be described with very simple expressions, when a hemisphere or an equivalent hemisphere replaces the actual electrode. Using the equivalent hemisphere representation, the required minimum length of the junction cable has been derived in the following steps:

- The Z-EPR of a hemispheric electrode at a distance x is given by:

$$V_x = \frac{\rho}{2\pi x} I$$

- The earthing potential V_e of the tower becomes:

$$V_e = R\,I$$

- By making the ratio of V_x / V_e the following expression is obtained:

$$\frac{V_x}{V_e} = \frac{\rho}{2\pi R} \frac{1}{x}$$

- Finally, the minimum distance x_{min} from the centre of the electrode, where the earth potential V_x is equal to a stipulated value, can be obtained as:

$$x_{min} = \frac{1}{2\pi} \frac{\rho}{R} \frac{V_e}{V_x}$$

where the following values are assumed to be known:

- ρ the specific resistivity of the surface soil at the location of the tower holding the RBS
- R earthing resistance of the tower holding the RBS (the value considered in Appendix I of K.57)
- V_e potential rise of the tower holding the RBS (the value obtained according to Appendix I of K.57)
- V_x admissible no load earth potential at the remote end of the junction section, i.e. at the junction point.

When the junction cable is laid along a straight route, then x_{min} is equal to the required minimum length of the junction section.

The ρ/R ratios have been determined by the CDEGS program for a series of actual tower footing arrangements (they are actually 21 different cases listed in tables of K.57).

- Taking $\rho/R = 18$, which covers about half of the calculated 21 cases, the above derived formula gives:

$$x_{min} = \frac{1}{2\pi} 18 \frac{V_x}{V_e} = 2.9 \frac{V_x}{V_e}$$

When the earthing electrode potentials (V_e) are considered according to the following isolating reference voltage levels

10 kV, 15 kV, 20 kV and 50 kV

and the permissible stipulated no load earth potentials at the conversion cabinet (V_x) for copper telecom cable or at the junction points are given as

650 V or 1 kV, 1.5 kV and 2 kV,

the minimum lengths of the junction sections calculated by the expression for x_{min} can be seen in Table 3.

3.2 Control of the touch- and step voltage by PGE

Both the field measurements [2] and the simulation calculations have shown that the soil potential (referred as Z-EPR) in the vicinity of the earth electrode sys-

Table 3: Minimum required lengths of the junction section corresponding to the isolation voltage levels and admissible Z-EPR at the junction point

Isolation voltage level	Minimum length, [m]			
	to conversion cabinet for copper telecom cable 1)	of the junction section		
	Admissible EPR at the junction point, V_x			
[kV]	650 V	1 kV	1.5 kV	2 kV
10	44	29	19	14
15	67	43	29	22
20	28	58	39	29
50	221	144	96	72

1) *Note: See Figure 14*

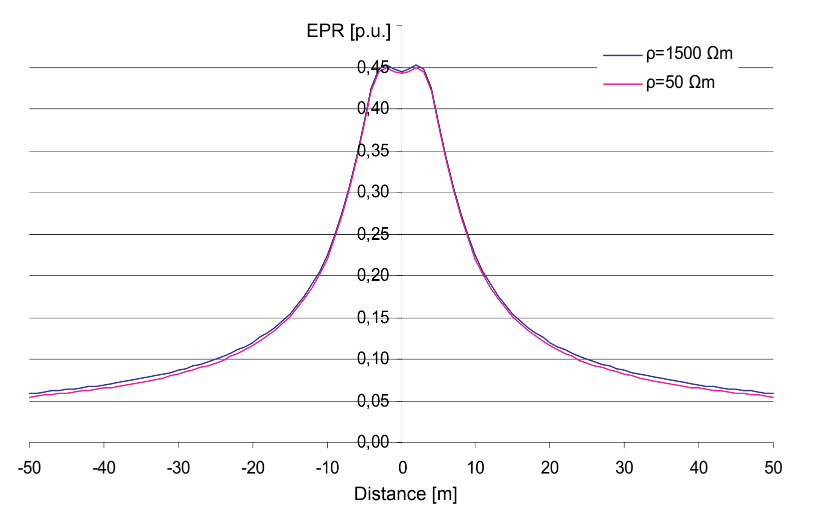
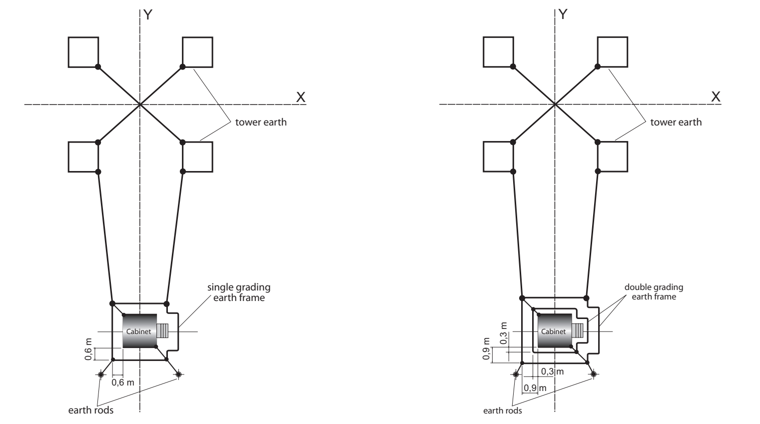


Figure 5: Profiles of EPR, normalised by the tower potential, at depth of 0.5 m perpendicular to the route of line through the centre point between the legs of the tower



a) Application of single PGE frame

b) Application of double PGE frame

Figure 6: Application of the PGE system when the cabinet is located beside the tower

tem of a power line tower (Figure 4) is significantly lower than the T-EPR. On the other hand, its profile shows high gradient, i.e. a rapid change (Fig. 5). As consequences of these facts, both the touch voltage occurring on the cabinet body bonded with the tower, and the step voltage around the cabinet can be very significant in magnitude.

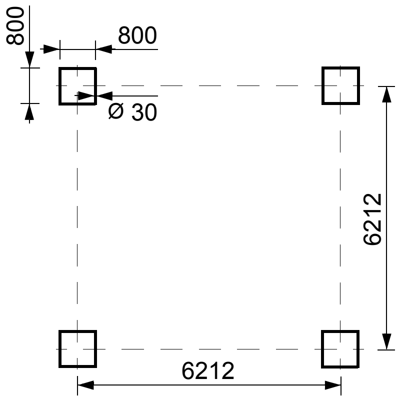


Figure 4: Arrangement and sizes (in mm) of earthing electrodes of a 220 kV power line considered in the EPR simulation; depth of electrodes: 1.7 m

For controlling the step and touch voltages the Potential Grading Earth (PGE), i.e. an electrode system laid at small depth (typically 0,3 m) around the equipment cabinet(s), is an effective tool for controlling the step and touch voltages. It shall be bonded to both the tower and the cabinet(s) earth.

The arrangements of PGE system are shown when the cabinet is located beside the tower or between the tower legs in Figure 6 and Figure 7, respectively.

The reduction effect of the grading frames on the touch voltage can be summarized in the following statements:

- A single PGE frame reduces the touch voltage by a factor of about 0.5 in relation to that condition when no PGE frame is applied. This reduction level occurs in a narrow zone just above the PGE electrode. The reduction rate can be even below 0.25, when the cabinet is beside the tower.
- The application of a second grading frame provides an additional reduction rate of 0.33 to 0.50. This reduction level affects a wider zone above the double PGE frames.

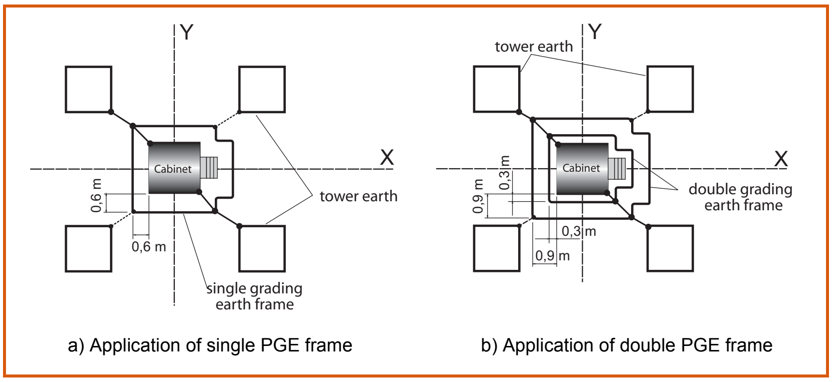


Figure 7: Application of the PGE system when the cabinet is located between the tower legs

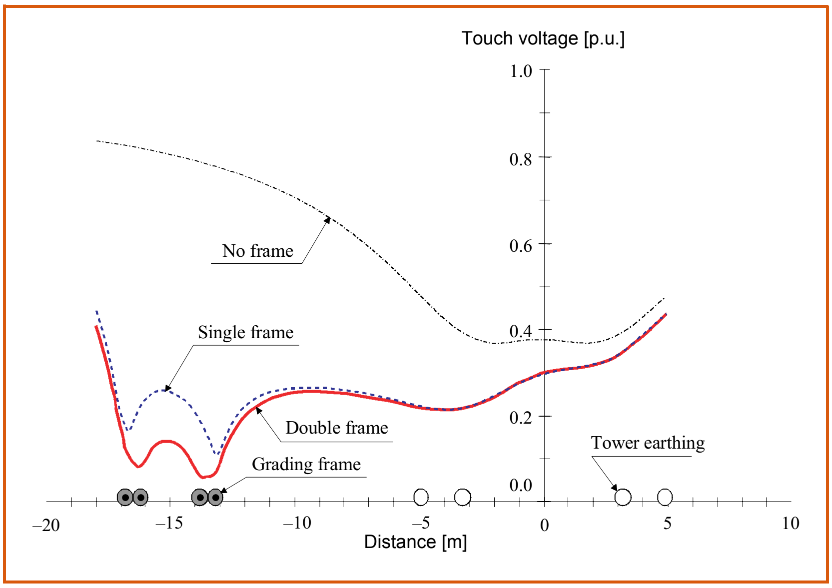


Figure 8: Profile of touch voltage (base: T-EPR) for cabinet beside the tower. Profile: Y direction, in centre line of the grading frame and tower-earthing electrodes

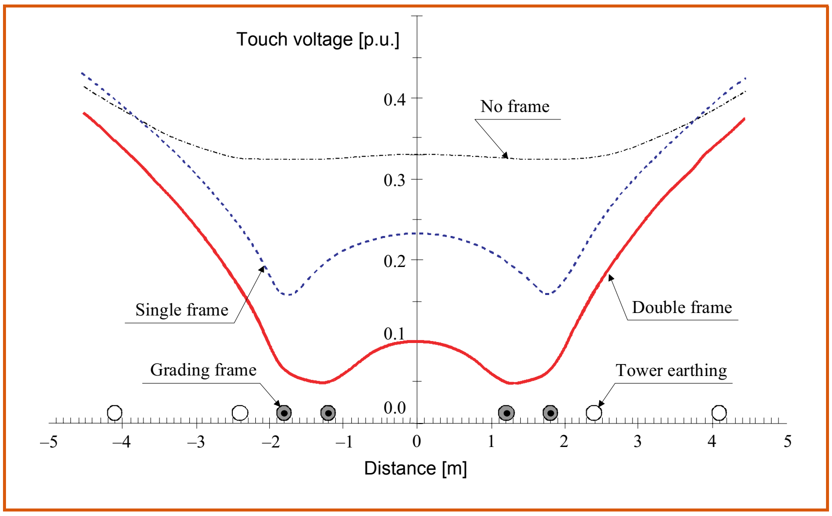


Figure 9: Profile of touch voltage (base: T-EPR) for cabinet between the tower legs Profile: X direction, in centre line of the PGE frame

The effectiveness of the use of PGE is demonstrated also for those two cases when cabinet is located beside the tower or between the tower legs in Figure 8 and Figure 9, respectively.

The step voltage is given by the gradient (steepness) of the earth potential profiles. The following statements can characterize the effect of the PGE electrode system on the step voltage:

- the application of the grading frames practically does not affect the step voltage outside the outer grading frame
- the step voltage is significantly reduced in the zone above the double PGE electrode frames
- the step voltage is practically identical for the single and double PGE frame systems outside the outer grading frame.

4. Power supply and protection

The RBS equipment may be powered in the following ways:

- From the LV network through an isolating transformer in order to separate the EPR area from the surrounding. This is most commonly used.
- From a MV power network. In this case you can use the MV/LV transformer as isolation between the EPR area and the surrounding.
- From the HV power line itself for example through capacitive voltage divider, capacitive coupled conductor or inductively coupled loop. No technically finished and economical method is available for this feeding method and used in hardly any.

4.1 Feeding from LV network

Typical arrangement of LV feeding system is shown in Figure 3, when the equipment cabinet is powered from the LV network.

The protection of LV feeding system involves the protection against power frequency (50 Hz) overvoltages due to earth faults and the impulse stresses caused by the lightning strokes to the tower hosting the RBS.

Protection against power frequency EPR

The principle of the protection is the isolation of the LV feeding system, entering the Z-EPR against the potential rise. The potential of the conductors of the feeding line is fixed to remote earth. (The phase conductors are earthed through the neutral earthing [assuming TN system] while the neutral and the cable screen, if applied, are directly earthed.) The primary winding of the isolating transformer is also on the potential of the remote earth due to its metallic connection to the feeding line. On the other hand, the neutral of the secondary winding is bonded to the tower earthing.

Under the above conditions, the protection can be provided by the appropriate:

- isolation of the primary (delta) winding of the isolating transformer with respect to the secondary winding, the iron core and any other metallic part of the cabinet
- isolation of the phase conductors and any metallic part (neutral screen) of the LV junction cable with respect to any earthed part of the cabinet and tower, and to the earth in the Z-EPR zone
- power frequency withstand of the SPD (MOV or similar device), i.e. appropriate selection of its rated voltage U_r.

Protection against lightning-generated surges

When lightning strikes a tower hosting an RBS, the majority of the lightning current is flowing to the earth through the earthing of the tower. Thus a similar, but impulse type EPR occurs as the EPR due to earth fault currents as described above. The magnitude of the impulse type tower T-EPR is essentially determined by the product of the magnitude of the lightning current and earthing impedance of the tower. Their ranges are for the lightning current 10 to 100 kA peak and for the earthing impedance 5 to 20 ohm. Therefore, the tower potential rise ranges from 50 to 2000 kV (Typical value: 50 kA × 10 ohm = 500 kV peak).

Apart from what is described in the different options below, the following shall be observed:

- The cable shall not be stapled towards earthed parts in the transformer cabinet.
- The cable shall approach the cabinet perpendicular to the power line in order to avoid induced voltages.
- If the ground does not allow buried cable, aerial cable may be used.
- In order to protect the LV network, other measures have to be fulfilled, that may be required by the LV network operator.
- As an alternative to a LV cable in plastic pipe a MV cable, which has the required insulation level, may be used for power supply. This shall be installed at least 50 m nearest to the tower. The MV cable shall not contain screen, i.e. MV cable manufactured without screen for this purpose is required.

The applicable protection practice, such as the way of connection and selection of SPDs, is significantly affected by the feeding arrangement, especially the structure of the junction cable that together with the isolating transformer are commonly protected with the SPDs applied at the feeding cabinet of the RBS. K.57 describes the following three options for the scheme and protection of the LV feeding system.

In the case of option 1 the junction cable has no metallic screen and neutral, the metallic parts of the cable are only the three phase conductors. The voltage stresses (lightning impulse and 50 Hz potential rise) occur between the phase conductors and the earth.

Regarding the ways of providing the appropriate insulation with respect to the earth the options are the following:

- LV three-core cable with additional increase of isolation to earth. The additional isolation shall be provided by insulating jacket on the cable or placing the junction cable in watertight insulating tube.
- MV cable without metallic screen (may be manufactured by special order).

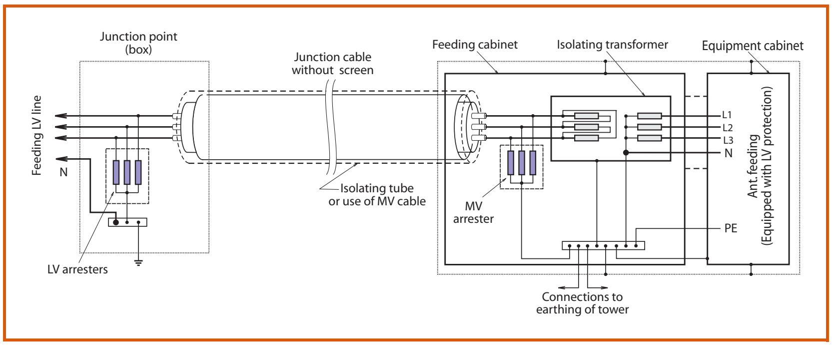


Figure 10: Junction cable without screen protected by MV arresters at the feeding cabinet and LV SPD at the junction box connected between each phase conductor and the earth

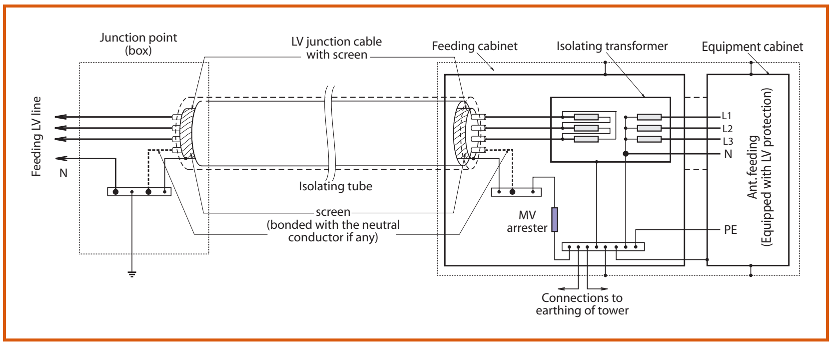


Figure 11: Junction cable with metallic screen protected by a single MV arrester

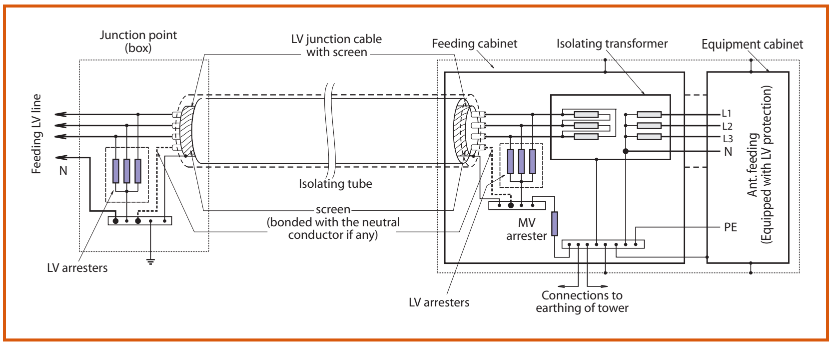


Figure 12: Junction cable with metallic screen protected by LV arresters in addition to a single MV arrester

In this case the required isolation to earth is provided by essentially the core insulation itself, which is further increased by the plastic sheath (jacket) of the cable. As an option, the cable may be three single-core cables.

The protection scheme for junction cable without screen can be seen in Figure 10 and it shows the type and ways of connection of SPDs:

- At the feeding cabinet the MV SPD (e.g. MOV) is connected between each phase conductor and the tower earthing
- At the junction point the LV SPD is connected between each phase conductor and the earth.

In the case of option 2 the junction cable has metallic screen or neutral. The typical cable is the LV three-conductor cable with concentric copper wire screen around the core bundle.

When a four-core screened LV cable is used, the neutral conductor shall be bonded to the screen at the terminals of the junction cable. According to the protection principle, the screen is earthed at the junction point (outside the EPR zone), thus the voltage stresses (lightning impulse and 50 Hz potential rise) occur between the screen and the earth especially in the vicinity of the tower. The required isolation to earth shall be provided by additional insulating jacket on the cable or placing the junction cable in watertight insulating tube.

The screen carries the surge current diverted by the MV SPD, thus its total cross-sectional area shall be at least 35 mm^2.

The type and ways of connection of SPDs are classified in the following two options:

- Applying MV SPD arrester only to the screen. According to this protection scheme the type and ways of connection of SPDs are as shown in Figure 11. At the feeding cabinet a single MV SPD arrester is connected between screen and the tower earthing. At the junction point the screen is directly earthed and no LV SPD at all is applied. When applying this protection scheme, it is assumed that the voltages of the phase conductors are, practically, equalized with the voltage of the screen due to the close inductive and capacitive coupling between the screen and the phase-conductors.
- Applying the combination of MV SPD arrester and LV SPDs (Figure 12). In the case of option 3 the same LF feeding structure is assumed as in option 2. The difference is in the application of LV type SPDs between the phase conductors and the cable screen at both terminations of the junction cable. The aim of this protection scheme is the voltage equalizing between the screen and the phase conductors ensured by the LV SPDs.

The connecting line, between the junction and coupling points including the coupling point itself, should be protected according to requirements to low-voltage power distribution systems such as given in IEC 61643-1 [7] and IEC 61643-12 [8]. The protection scheme, especially the bonding and earthing conditions shall also comply with the requirements for subscriber premises given in Recommendation K.31.

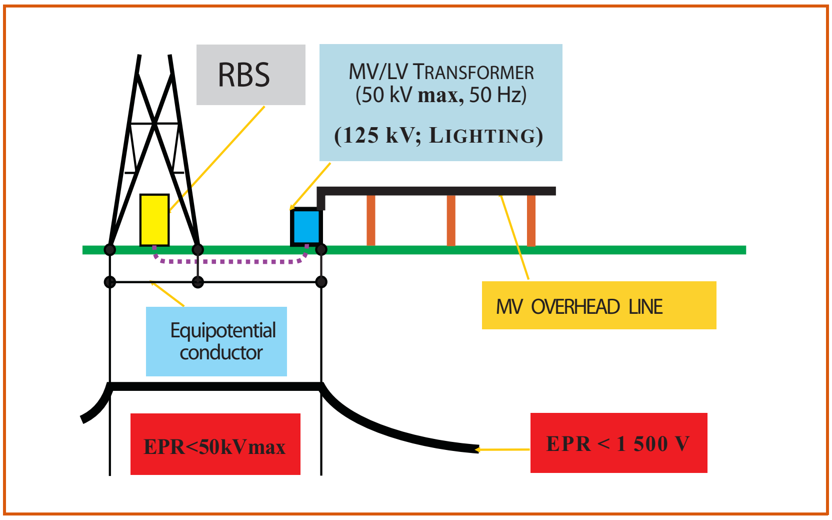


Figure 13: MV power feeding of RBS

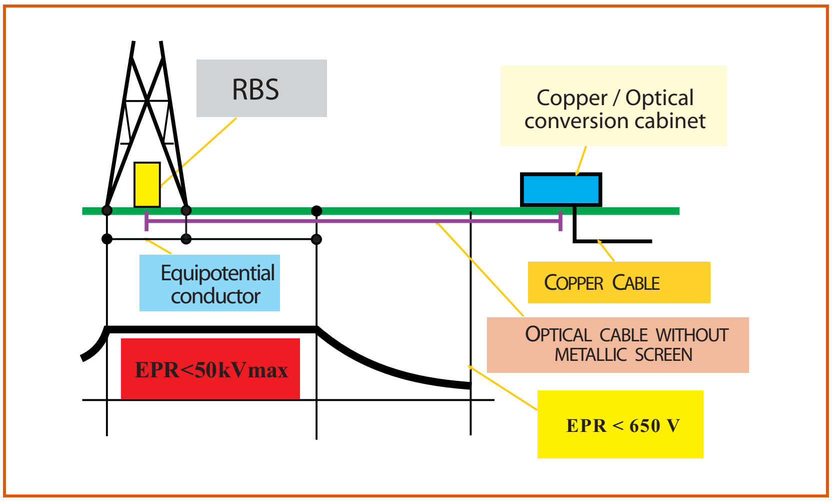


Figure 14: Connection to telecommunication network via optic fibre

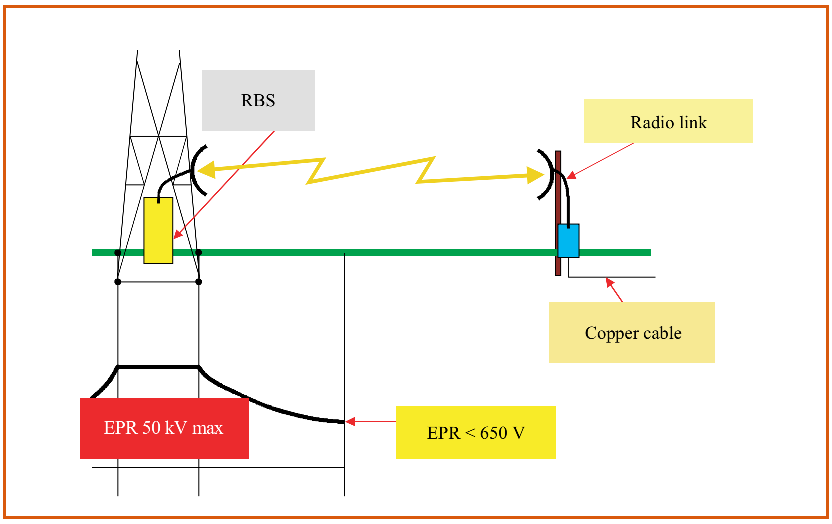


Figure 15: Connection to telecommunication network via radio link

4.2 Feeding from a MV network

As an alternative the equipment cabinet may be powered from a distribution network, typically 10 to 20 kV. There are two options of the feeding from MV network corresponding to the location of the MV transformer feeding the RBS.

When the RBS is fed from MV/LV transformer and located *in* the zone of EPR (Figure 13), the following type of protection means shall be applied:

- Equalizing through a copper wire of at least 35 mm^2 between the HV tower earthing and the earthing bar at the transformer
- MV SPD (e.g. MOV or similar) arrester connected between each phase conductor on the MV side and the earthing bar at the transformer. This is normally applied to protect the transformer against lightning surges coming from the MV line.
- LV type SPD is connected between each phase conductor and the tower earth in the feeding cabinet of the RBS. This LV type SPD is applied for the protection of the equipment of the RBS.
- When the RBS is fed from MV/LV transformer located *out* of the EPR zone (but less than 50-60 m), the applicable protection scheme is the following:
- The LV/LV isolating transformer shall be installed in the feeding cabinet.
- The LV feeding line is considered as junction section; therefore it shall be protected according to schemes described in section 4.1.
- MV SPD shall be connected between each phase of the MV side and the earthing at the MV/LV transformer. This is normally applied to protect the transformer against lightning surges coming from the MV line. The MV SPD may not be necessary when the transformer is fed by well-shielded MV cable.

4.3 Feeding from the HV line

No method justified technically and economically is known at present. This method of feeding the RBS is therefore not recommended.

5. Additional requirements on the antenna system

General requirements on RBS located on antenna towers are given in the technical specifications [6] and [9].

The requirements on the installation of the RBS sited on power line towers are the following:

- Coaxial cables between equipment cabinet and antenna(s) shall be placed in a suitable way in dedicated cable ducts or clamped to the tower structure, in order to get unhindered maintenance and fault repair of the equipment and the tower.
- Underground cables between equipment cabinet and tower shall be laid in isolated pipes.
- Communication equipment, antenna and accessories shall be type approved according to national regulations and requirements.
- The antennas will be placed in strong electric fields, where they may be exposed to corona and sparks. The owner of the antennas must be aware of this in order to avoid degraded function of the antennas.
- Depending type of tower and location of the antenna(s), the levels of electric and magnetic field strengths from the power line may be achieved from the power company.
- If antennas are placed above the overhead earth wires, they shall be provided with lightning protection [6].

6. Telecommunication links

When wire communication link is applied, in order to avoid problems of induction and EPR at earth faults, the telecommunication should use metal-free fibre optic cables (see Figure 14).

If metallic cables are used for the telecommunication, they shall be constructed and connected under the same conditions as the LV power supply. It means that they shall:

- have an adequate isolation level
- be laid in an insulating, water-tight, plastic tube
- be terminated via a transformer
- be provided with feasible over-voltage arrestors.

The transition point should not be closer than the point, where the EPR is expected to be 650 V. This voltage level is the limit for short-term overvoltage with a duration of 0.5 s. Other levels may be chosen with reference to ITU-T Rec. K.33 [4].

Further information is given for the separation in the soil between telecommunication cables and earthing system of power facilities in the ITU-T Rec. K.8 [3].

When radio communication link is applied, which is a preferred technique for RBS sited on power line tower, the installation arrangement is shown as an example in Figure 15.

7. Installation and maintenance

Installation and maintenance of the equipment located in the tower such as antennas and cables, is restricted to people specially trained with knowledge about electric and magnetic fields from power lines, normally linesmen of the power company. However, special caution has to be observed concerning the risk of exposure to electromagnetic fields from the RBS antenna(s). For guidance see ITU-T Recommendation K.52 [5].

The installations on ground are normally done by specially instructed RBS people. National regulations may require further restrictions on this type of work.

References

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[4] ITU-T Recommendation K.33: *"Limits for people safety related to coupling into telecommunications system from a.c. electric power and a.c. electrified railway installations in fault conditions"*, Oct. 1996

[5] ITU-T Recommendation K.52: *"Guidance on complying with limits for human exposure to electromagnetic fields"*, Febr. 2000

[6] ITU-T Recommendation K.56: *"Protection of radio base stations against lightning discharges"*, Aug. 2003

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[8] IEC 61643-12 Low-voltage surge protective devices - Part 12: Surge protective devices connected to low-voltage power distribution systems - Selection and application principles; First edition, Febr. 2002

[9] ETSI Guide, Electromagnetic compatibility and Radio spectrum Matters (ERM); Radio site engineering for radio equipment and systems, ETSI EG 200 053 V1.4.1, June 2002

APPENDIX

Introduction

This Appendix contains a compilation of the comments received from the questionnaire, that was circulated among the member countries of ITU-T and CIGRÉ SC 36, now SC C4, in the autumn of 2001. Many responders also attached figures and photos of solutions and installations.

It is acknowledge, that the answers to the questionnaire constitute a worldwide experience of radio base stations sited in power line towers - an experience, which is incorporated in ITU-T recommendation K.57.

A summary of the answers as well as the questionnaire itself is attached.

General

Among the countries that have answered the European countries, Australia, Canada and USA use high voltage, HV (> 100 kV) towers for locating Radio Base Station antennas and transmitting equipment. Some also use medium voltage, MV (1 - 100 kV) towers, which also is the case in Japan and Thailand.

Many countries avoid placing the antennas above top earth wires to minimize the risk of lightning striking them. Some locate the antennas below the phase conductors in order to make maintenance possible during operation of the HV line.

The equipment cabinet is normally placed between the tower legs, on elevated platform or very close to the tower, because they need a common earthing system.

The power feeding of the equipment is the crucial point. The used options are feeding from the LV public network, which is most common, or feeding from the MV network, the use of which depends normally on the accessibility to a LV network in the proximity of the site.

The benefit of feeding from a MV network is, that the normal MV/LV transformer may serve as isolating transformer. In densely populated urban areas, earth potential rise, EPR, is so low and the potential equalizing so effective, that there is no need for an isolating transformer.

Safety & disturbances

Concerning safety, there are different restrictions and legal instructions from authorities, which have to be followed. Some countries allow working in a power line tower, when in operation. There is also special attention taken to the risk of being exposed to RF radiation.

There are general restrictions of working in towers during thunderstorms.

There is very little experience concerning disturbances from the HV and MV systems into the radio antennas. See table below.

Special comments

Many electricity companies use overhead earth wires all through their HV network. This is of benefit to the EPR at earth faults. However, in areas with low earth resistivity, some companies only have earth wires a few kilometres close to the substations.

Feeding cables from the cabinet to the antenna are installed in a metallic pipe or on cable ladders bonded to the tower structure.

Many have regulations that forbid working in a tower above the phase conductors during HV operation. In order to avoid power outages, the location of any antennas must be below the phases. Others use safe distances to live conductors of 2 m.

All maintenance in the tower are made by special power company personnel.

The installation of the transmitting equipment in a cabinet as well as its earthing grid may be done by the wireless company. Special attention is taken to the bonding of the copper earthings to the galvanized steel tower in order to avoid corrosion. Cathodic protection may be needed.

In answering the questionnaire some have attached photos and articles, which have been published earlier, see the Bibliography and Photos below.

Bibliography

[1] van WAES, van Riet, van Deursen, Provoost and Cobben: "*Experimental study on safety aspects of cellular phone systems in HV towers*" CIRED 2001

[2] G. Lessard and Y. Rajotte: "*Safety issues related to the connection of MV and HV grounding systems outside substations*", Transmission and Distribution Construction, Operation and Live-Line Maintenance Proceedings. 2000 IEEE ESMO - 2000 IEEE 9th International Conference on Safety, Maintenance and Operations, 8-12 Oct. 2000, pp. 375 - 381

[3] Y. Rajotte, J. Fortin and G. Lessard: "*Safety issues related to the connection of MV and HV grounding systems outside substations*", 16th CIRED Conference, 2001, Paper 2.14

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Questionnaire

Use of Power Line Poles for Radio Base Stations.

Information

Name:

Company :

Country :

General

Description of the power system used for radio base antennas.

High voltage (> 100 kV)	YES ☐		NO ☐
Directly earthed neutral?	YES ☐		NO ☐
Earth wire(s) on top of poles?	YES ☐		NO ☐

Comment:

Medium voltage (< 100 kV)	YES ☐		NO ☐
Directly earthed neutral?	YES ☐		NO ☐
Earth wire(s) on top of poles?	YES ☐		NO ☐

Comment:

Location of antenna(s)?

Below the phase conductors?	YES ☐		NO ☐
Above the phase conductors?	YES ☐		NO ☐
Below the earth wires, if any?	YES ☐		NO ☐
Above the earth wires, if any?	YES ☐		NO ☐

Comment:

Location of equipment cabinet?

Between the legs of the pole?	YES ☐		NO ☐
Beside and close to the pole?	YES ☐		NO ☐
At a minimum distance from the pole?	YES ☐	m	NO ☐

Comment:

Location and way of installation of the cables between the cabinet and the antenna(s)?

(Connections of the screen to the pole and the cabinet, installation in metallic pipes etc)

Description in words or attach a figure:

How is the voltage drop in the tower during earth fault managed?

Are there any special considerations concerning lightning protection?

Others?

Power feeding?

From the HV line itself?	YES ☐	NO ☐
From a MV distribution network?	YES ☐	NO ☐
From the LV network?	YES ☐	NO ☐

How is the earth potential rise during earth fault (or double earth faults) managed?

How is safety managed?

Safety of people?

During installation?

During operation?

Mitigation techniques:

Have you experienced any disturbances?

Due to corona?	YES ☐	NO ☐
Due to sparks?	YES ☐	NO ☐

If yes, what kind of disturbances?

Summary of the replies on the questionnaire

Question subject	Information from																					
	AUSTRALIA	EUROPE										NORTH AMERICA									ASIA		
Parameter \ Answer no.	1	2	3	5	6	7	8	11	12	13	14	4	16	17	18	19	20	21	22	23	9	10	15
High voltage	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	
Directly earthed	Y	Y	Y	N		N	Y	Y	N	Y	Y	Y	Y	Y	Y	N	Y	N	N			N	
Top earth wires	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y				Y	
Comment	Y	Y	Y	Y	Y		Y	Y								Y		Y	Y	Y			
Medium voltage		Y	Y		Y	Y	N	N	N	Y	N	N	Y	N	Y	Y	Y	N	Y		Y	N	Y
Directly earthed		Y	Y			N		N		N			Y	N	Y	Y	Y		N		N		
Top earth wires		Y	Y			Y		N		N			Y	N	N	Y	Y		N		Y		
Comment	NA		Y	Y				Y							Y	Y	Y	Y					
Antennas below phases	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y		Y	Y	
above phases	Y	Y	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y		Y	N	
below top wires	Y	Y	Y	Y	Y	N	Y	Y	N	Y	Y	Y	Y	N	Y	Y	Y	Y	Y		N	Y	
above top wires	Y	Y	N	N	N	N	N	Y	N	N		N	Y	N	Y	Y	Y	Y	Y		Y	N	
Comment						C		Y								Y	Y	Y			F	F	F
Cabinet btw legs of pole	Y	Y	Y		Y	Y	Y	Y	Y	N	Y	Y	Y	Y	N	Y	Y	Y	Y		N	Y	Y
Beside and close	Y	Y	Y		N	Y	N	Y	N	N	Y	N	Y	Y	N	Y	Y	Y	Y		Y	Y	
Min distance	3m	3m	N		N	N	N	N	N	10m		N	N	N	5m	100m	5m	N	N		N	3-4m	1m
Comment	Y					Y		Y			Y	F		Y	C	Y	Y	Y			F	F	F
Location & installation	C	C	C	C	C	C	C	C		C	C		C	C	C	C	C	C	C		C	C	F
Power feeding HV		N	N	N		N	N	N		N	N	N	N	N	N	N	N	N	N		N	N	
MV		Y	N	N		Y	N	N		N		Y	N	N	Y	N	Y	N	Y		N	N	
LV	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y		Y	Y	Y	Y	Y	Y	Y		Y	Y	Y
Isolation trafo	Y	Y	Y			Y	Y	Y		Y		Y						Y					
Comment		Y	Y	Y	Y	Y	F				Y	C	!	Y	Y		Y	Y	Y		Y	Y	F
Safety during installation	Y	Y	N				Y	Y		Y	Y	Y		Y	Y		C	Y	Y		Y	Y	Y
maintenance	Y	Y					Y	Y		Y	Y	Y		Y	Y		C	Y	Y		Y	Y	Y
Comment				Y	Y	Y				Y	Y			Y	Y	Y	Y	Y	Y		Y	Y	Y
Disturbances corona	N	Y	N		N	N	N	N		N	(Y)	N	N	N	N	N	N	N	N		N	N	Y
sparks		N	N		N	N	N	N		N	(Y)	N	N	N	N	N	N	N	N		Y	N	Y
Comment	Y	Y		C							C										C		F
Figures					Y							Y									Y	Y	Y
Other comments			Y									Y					Y	Y			Y		

Abbreviations: Y = Yes, N = No, C = Comment, NA = Not Applicable, F = Figure