



IEEE Guide for Surge Protection of DC Power Feeds to Remote Radio Heads

STANDARDS

IEEE Power and Energy Society

Developed by the
Surge Protective Devices Committee

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(Revision of
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Developed by the

Surge Protective Devices Committee
of the
IEEE Power and Energy Society

Approved 4 June 2020

IEEE SA Standards Board

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Abstract: The waveform of currents likely to exist on dc feeds to equipment located at the tops of towers due to a lightning strike, and the consequences of that waveform for protector design, are described in this guide.

Keywords: IEEE C62.55™, lightning, powering feed, protection, remote radio head, RRH, SPD, surge protective device, surge waveform, towers

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3 Park Avenue, New York, NY 10016-5997, USA

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Participants

At the time this IEEE guide was completed, the WG3.6.7 Working Group had the following membership:

Albert Martin, *Chair*
Ernest Gallo, *Vice Chair*

Tim Ardley
Daniel Ashton
Frank Basciano

Leonard Drewes
Peter Kobsa

Mick Maytum
Wolfgang Oertel
Thomas Tran

The following members of the individual Standards Association balloting group voted on this guide. Balloters may have voted for approval, disapproval, or abstention.

Frank Basciano
Demetrio Bucaneg Jr.
Raymond Hill
Werner Hoelzl
Yuri Khersonsky

Albert Martin
Mick Maytum
Wolfgang Oertel
Bansi Patel
Percy Pool
Bartien Sayogo

James Timperley
John Vergis
Matthew Wakeham
Lanyi Wang
Jian Yu

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Dong Liu
Kevin Lu
Paul Nikolich
Damir Novosel
Dorothy Stanley

Mehmet Ulema
Lei Wang
Sha Wei
Philip B. Winston
Daidi Zhong
Jingyi Zhou

*Member Emeritus

Introduction

This introduction is not part of IEEE Std C62.55-2020, IEEE Guide for Surge Protection of DC Power Feeds to Remote Radio Heads.

This revision of IEEE Std C62.55-2017 includes the corrections indicated in IEEE Std C62.55-2017/Cor 1-2018, and updating the clause on multiple strokes and continuing current. It also includes updates to the original 2017 version.

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IEEE Guide for Surge Protection of DC Power Feeds to Remote Radio Heads

1. Overview

This guide begins by discussing the characteristics of [lightning flashes having a](#) single stroke ~~lightning~~ that might strike a tower. The nature of the resulting current on the dc feed ~~is~~ ~~are~~ then discussed. Next, consideration is given to lightning flashes having multiple strokes. Finally, guidance on selecting a surge protective device (SPD) for the dc feed and practical considerations are discussed.

1.1 Scope

This guide covers the application of SPDs used to protect the dc power feeds of remote radio heads (RRHs) and power supplies of [optical](#) fiber-~~optic~~ cable systems feeding the antenna systems.

1.2 Word usage

[The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted \(*shall* equals *is required to*\).^{1,2}](#)

[The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required \(*should* equals *is recommended that*\).](#)

[The word *may* is used to indicate a course of action permissible within the limits of the standard \(*may* equals *is permitted to*\).](#)

¹[The use of the word *must* is deprecated and cannot be used when stating mandatory requirements, *must* is used only to describe unavoidable situations.](#)

²[The use of *will* is deprecated and cannot be used when stating mandatory requirements, *will* is only used in statements of fact.](#)

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can* equals *is able to*).

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

CIGRE TB 549, Lightning Parameters for Engineering Applications, ~~WG C4.407~~, 2013. ³⁴

IEEE Std C62.33™, IEEE Standard for Test Methods and Performance Values for ~~of~~ Metal-Oxide Varistor Surge Protective Components. ^{4,5} ~~2,3~~

ITU-T Recommendation K.97 (2014), Lightning protection of distributed base stations. ⁶⁴

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause. ⁷⁵

³⁴CIGRE publications are available from the Council on Large Electric Systems (<http://www.e-cigre.org/>).

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⁷⁵*IEEE Standards Dictionary Online* is available at: <http://dictionary.ieee.org>. An IEEE Account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.

remote radio head (RRH): The radio frequency (RF) module of a radio base station (RBS), which can be installed separated from the base band unit (BBU). [adapted from ITU-T K.97(2014)]

NOTE 1—Optical fiber is commonly used to connect the BBU to the RRH. 86

NOTE 2—The RF radio-frequency module is also called remote radio unit (RRU).

3.2 Acronyms and abbreviations

BBU base band unit

DUT device under test

FTTA fiber to the antenna

~~ICT—information and communication technology~~

MOV metal-oxide varistor

RBS radio base station

RF radio frequency

RRH remote radio head

SPD surge protective device

TVS transient voltage suppressor

86 Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the standard.

4. The problem

Antennas at tower tops are predominately fed by coax from radio equipment at the base of the tower. To reduce transmission losses and mechanical loading on the tower, RRHs are placed at the top of the tower next to the antenna. Optical fiber cables carrying the signal information are run up to the RRH equipment, where the optical signals are converted into [radio frequency \(RF\)](#) power to drive the antennas. The RRH is generally powered by a low voltage dc line (typically 48 V) run up to the equipment from a power supply at the base of the tower. Towers can be over 610 m (2000 ft) tall, and the lightning surges to these towers can have very high I^2t (the lightning action integral). Consequently, the potential for RRH damage due to surges on the power feed is high and surge protection is important to protect the RRH from possible damage. Thus, the problem considered is the nature of the surge on a dc power feed due to a lightning strike to the tower and how that impacts the design or selection of a protector.

5. Lightning characteristics

5.1 General

There are basically four types of lightning as shown in Figure 1. The important parameters of these types are the manner in which the flash is initiated and the polarity of the flash.

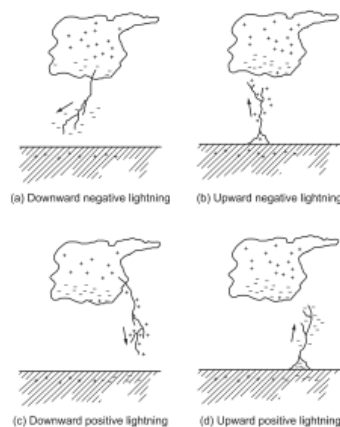


Figure 1—Types of lightning

5.2 Downward leader and negative charge polarity

~~5.2 Type (a)~~

Type (a) flashes have a downward leader and negative charge polarity [see Figure 1(a)]. About 90% of all lightning is this type. It characterizes ground flashes and flashes to short towers. Most of the existing data is for this type of lightning; most equipment will be subject to it (unless the equipment is on a higher tower). The characteristics of type (a) lightning are described in Table 3.5 of CIGRE TB 549 (2013).⁹

5.3 Downward leader but positive charge polarity

~~5.3 Type (c)~~

Type (c) flashes have a downward leader but positive charge polarity [see Figure 1(c)]. About ~~13~~ 10% of all lightning is this type , with the highest amount (close to 25%) in January and February. It characterizes ground flashes and flashes to short towers. There is less data for this kind of lightning, but it still needs to be considered, especially for the protection of equipment on low towers. The characteristics of Type (c) lightning were discussed in the 2012 ATIS Protection Engineers Group (PEG) Conference (Martin [B12]¹⁰). Based on the 2005 data in Martin [B12], these characteristics are shown in Table 1.

Table 1—Parameters of type (c) lightning

Parameter	Median	Sigma
Peak amplitude (I_p), kA	35	1.21
10–90 rise time (T_{10}), μ s	17.6	1.23
Fall time (t_f), μ s	230	1.33

⁹[Information on references can be found in Clause 2.](#)

¹⁰[The numbers in brackets correspond to those of the bibliography in Annex B.](#)

5.4 Negative or positive charge polarity but an upward leader

~~5.4 Types (b) and (d)~~

Type (b) flashes have negative charge polarity, but an upward leader [see Figure 1(b)]. This type of lightning occurs only to relatively tall towers. It is infrequent and the database for it is small, most of it going back to ~~the~~ Berger, Anderson, and Krominger, et al. 1975 ~~paper~~ [B1]. For tall towers, protection design should be based on the data (however limited meager) for this type of lightning.

Type (d) flashes have positive charge polarity and an upward leader [see Figure 1(d)]. This type of lightning occurs only to relatively tall towers. It rarely occurs, but the effects can be large when it does. Because there is so little data on Type types (b) and Type (d) lightning, data for both are combined in one table in Table 7.3 of CIGRE TB 549 (2013).

6. The meanings of “short” and “tall”

6.1 Method of determination

In Clause 5, the terms “short towers” and “tall towers” have been used. How is the type of tower determined? The type of lightning expected can help in this determination. Tall towers get hit by the more severe upward flashes, low towers by the less severe downward ones. Which type to expect can be calculated using Equation (1) (from Eriksson [B7]):

$$P_u = 52.8 \ln(H_s) - 230 \quad (1)$$

where

P_u is the percentage of upward flashes

H_s is the structure height (meters)

This equation is valid only for heights ranging from 78 m to 518 m, because $P_u = 0$ for $H_S \leq 78$ m and $P_u = 100\%$ for $H_S \geq 518$ m. Structures with heights less than 78 m (250 ft) are expected to be struck by downward flashes only, and structures with a height of greater than 518 m (1700 ft) (there are some) are expected to experience upward flashes only.

To help understand the percent of upward flashes expected as a function of tower height, Equation (1) has been plotted in Figure 2 for the range of Equation (1).

Tall towers have a higher percentage of the more severe positive flashes. Therefore, for tall towers the table of values for upward flashes would be chosen. Lower towers would use the tables for downward flashes.

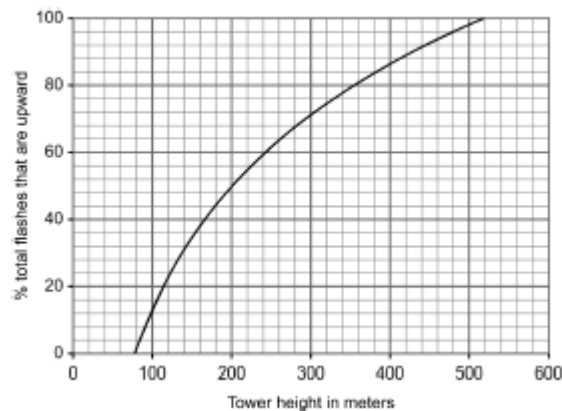


Figure 2—[The](#) plot of Equation (1). Factor by which the effective tower height H exceeds the actual height, where X is the ratio of mountain height to tower height.

6.2 Correction for towers on mountain tops

As pointed out by Zhou et al. [B31 B30], the effective tower height needs to be adjusted when the tower is located on a mountain. They give a series of equations that can be used to calculate the effective height of the tower, H . These equations can be written as follows:

$$H = \left(5.87 \times 10^{-3} + 2.04 \times 10^{-6} E_g \right)^{-1.394} \quad (2)$$

$$E_g = \frac{U_{ic} + 73\,400}{hy \left[1 - \frac{x^3}{y} \right]} \quad (3)$$

$$U_{ic} = \frac{1.556 \times 10^6}{1 + \frac{7.78}{R}} \quad (4)$$

$$R = \frac{2y}{1 + \frac{4y(xh)^3}{y^4 - (xh)^4}} \quad (5)$$

where

h is the height of tower (meters)

a is the height of mountain above surroundings (meters)

$x = ah$

$y = x + 1$

Table 2 gives some values of the factor by which the effective tower height exceeds the actual height, as a function of the ratio of the mountain height above surroundings to the tower height.

Table 2—Factor by which the effective tower height H exceeds the actual height h

	H/h for $h =$							
X	10	25	50	100	150	200	300	500
1	1.47	3.49	4.26	4.16	3.73	3.32	2.68	1.91
2	2.12	3.68	4.27	4.10	3.67	3.27	2.65	1.89
3	2.26	3.61	4.13	3.97	3.57	3.19	2.60	1.87
4	2.29	3.51	3.99	3.86	3.48	3.12	2.55	1.85
5	2.29	3.41	3.87	3.76	3.41	3.07	2.52	1.83
6	2.28	3.33	3.77	3.67	3.34	3.02	2.48	1.81
7	2.27	3.26	3.69	3.61	3.29	2.98	2.46	1.80
8	2.25	3.20	3.62	3.55	3.25	2.94	2.44	1.79
9	2.23	3.16	3.57	3.50	3.21	2.91	2.42	1.78
10	2.22	3.11	3.52	3.46	3.18	2.89	2.40	1.77
12	2.20	3.04	3.44	3.39	3.12	2.84	2.37	1.75
14	2.18	2.99	3.38	3.34	3.08	2.81	2.35	1.74
16	2.16	2.95	3.33	3.30	3.05	2.79	2.33	1.73
18	2.14	2.92	3.29	3.27	3.02	2.76	2.32	1.73
20	2.13	2.89	3.26	3.24	3.00	2.75	2.31	1.72
25	2.11	2.83	3.20	3.19	2.96	2.71	2.29	1.71
30	2.09	2.80	3.16	3.15	2.93	2.69	2.27	1.70
35	2.08	2.77	3.12	3.12	2.91	2.67	2.26	1.69
40	2.07	2.75	3.10	3.10	2.89	2.66	2.25	1.69
50	2.06	2.72	3.07	3.07	2.87	2.64	2.24	1.68
75	2.04	2.68	3.02	3.03	2.83	2.61	2.22	1.67
100	2.03	2.66	2.99	3.01	2.82	2.60	2.21	1.67

For example, for a tower 100 m tall on a mountain rising 300 m above its surroundings, the effective height of the tower is 397 m. Zhou et al. [B31] state that the maximum uncertainty of the values where $X \geq 5$ in Table 2 is 105% to 322%. Where $X \leq 4$ in Table 2, it is 20% to 65%. In either case, the values in Table 2 can be much larger or smaller than those shown.

Table 2 can be used in conjunction with Figure 2 to predict the percentage of upward flashes expected to hit the tower. In the absence of better information, it is reasonable to assume that tall towers will be struck mainly by flashes with upward leaders; which in turn suggests that values from Table 7.3 of CIGRE TB 549 (2013) be used to estimate the flash waveform.