IS 5613-1-1 (1985): Code of Practice for Design, Installation and Maintenance of Overhead Power Lines, Part 1: Lines Up to and Including 11 kV, Section 1: Design [ETD 37: Conductors and Accessories for Overhead Lines]

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IS : 5613 (Part 1/Sec 1) - 1985

Indian Standard (Reaffirmed 2002)

CODE OF PRACTICE FOR DESIGN, INSTALLATION AND MAINTENANCE OF OVERHEAD POWER LINES

PART 1 LINES UP TO AND INCLUDING 11 kV

Section 1 Design

(First Revision)

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Indian Standard

CODE OF PRACTICE FOR DESIGN, INSTALLATION AND MAINTENANCE OF OVERHEAD POWER LINES

PART 1 LINES UP TO AND INCLUDING 11 kV

Section 1 Design

(First Revision)

(*Continued on page* 2)

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Indian Standard

CODE OF PRACTICE FOR DESIGN, INSTALLATION AND MAINTENANCE OF OVERHEAD POWER LINES

PART 1 LINES UP TO AND INCLUDING 11 kV

Section 1 Design

(First Revision)

0. FOREWORD

0.1 This Indian Standard (Part 1/Sec 1) (First Revision) was adopted by the Indian Standards Institution on 22 January 1985, after the draft finalized by the Conductors and Accessories for Overhead Lines Sectional Committee had been approved by the Electrotechnical Division Council.

0.2 The design, installation and maintenance practice of overhead power lines varies widely from state to state and in various organizations. This variation leads to uneconomic designs and higher installation and maintenance cost. The necessity was, therefore, felt to prepare a standard on this subject which would result in unification of designs of overhead lines and also in savings in cost.

0.3 This standard was first published in 1970. The revision of this standard has been undertaken to include the developments that have taken place since the last publication of this standard.

0.4 This standard is being prepared in the following three parts:

Part 1 Lines up to and including 11 kV,

Part 2 Lines above 11 kV and up to and including 220 kV, and

Part 3 Lines above 220 kV.

Each part has been further divided in two sections. Section 1 covers design aspects and Section 2 covers installation and maintenance of overhead power lines.

0.5 In the preparation of this standard, considerable assistance has been derived from Rural Line Standards, Construction Manual, prepared by Rural Electrification Corporation Ltd, New Delhi.

0.6 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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1. SCOPE

1.1 This standard (Part 1/Sec 1) covers design of overhead power lines up to and including 11 kV.

1.2 Protection and control of overhead power lines is not covered in this code.

2. TERMINOLOGY

2.1 For the purpose of this code, the definitions given in IS : 1885 (Part 32) - 1971† shall apply.

3. GENERAL

3.1 Conformity with Indian Electricity Rules and Other Regulations — All overhead power lines shall comply with the latest provisions of Indian Electricity Rules and with any other regulations that may be applicable. The Rules No. 29, 61, 74 to 93 of the Indian Electricity Rules, 1956 are particularly applicable.

3.1.1 It is desirable that the local authorities concerned in the administration of the rules and regulations relating to choice of route, etc, be consulted in regard to the rules and regulations that may be applicable. Highways department and aerodrome authorities should also be consulted wherever the power lines run near or across the area under their jurisidiction.

3.1.2 All overhead power lines which cross railway tracks shall be laid in accordance with the rules stipulated in regulations for electrical crossing of railway track framed by Railway Board.

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*Rules for rounding off the numerical values (*revised*).

†Electrotechnical vocabulary: Part 32 Overhead transmission and distribution of electrical energy.

3.2 Before deciding the basic parameters of the line, information regarding the total load, including future extensions, point of supply or area to be covered, should be exchanged between the designer and distribution authorities. On the basis of this load and the length of the line the designer should predict the most economic system of voltage and conductor size.

3.3 For economical and practical reasons almost all present day power stations in the country generate electrical power at three-phase 50 Hz ac, while the transmission and distribution of power is done on 3-phase 3-wire at high voltages and 3-phase 4-wire for voltages up to 650 volts.

3.4 The transmission and distribution voltages have been standardized and are given in IS : 585-1962*.

3.5 Lines may be broadly classified as feeders and distributors. With feeders, the main consideration is economy and with distributors, it is the voltage drop.

3.6 Lines supplying mixed load are generally designed for a power factor of 0·8 lagging.

4. CHOICE OF VOLTAGE

4.1 The cost of the lines is one of the deciding factors in the choice of voltage. The general rule is that the voltage of the line is taken as 0·6 kV per km of the length of the line. For the purpose of this code, however, the voltage is limited to 11 kV and there is very little choice to be made; 3·3 kV and 6·6 kV lines are not very common these days except for the extensions of already existing lines or within industrial premises. The most common voltage for short distance lines is 11 kV while 415/240 V is used for distribution to consumers.

5. CHOICE OF ROUTE

5.1 The proposed route of the line should be the shortest practicable distance. The following areas should be avoided as far as possible:

a) Rough and difficult country,

b) Urban development,

c) High amenity area,

d) Restricted access for transport vehicles,

e) Abrupt changes in line route,

f) Way-leave problems,

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*Specification for voltages and frequency for ac transmission and distribution systems (*revised*).

g) Difficult crossings,

h) Natural hazards, and

j) Proximity to aerodromes.

5.1.1 Overhead lines should run away from the buildings containing explosives.

6. CONDUCTORS

6.1 Type of Line Conductors — There is a good range of conductors available these days for carrying power through overhead lines. The most commonly used conductors for distribution of power up to 11 kV are steel reinforced aluminium conductors (ACSR), all aluminium conductors, galvanized steel conductors and copper conductors.

NOTE — Due to the shortage of copper and zinc in the country, it is recommended not to use copper and galvanized steel conductors. Attention is drawn to the use of aluminized steel reinforced aluminium conductors and aluminium alloy stranded conductors. Requirements for these types of conductors have also been covered in the appropriate parts of IS : 398*.

6.1.1 *Steel Reinforced Aluminium Conductors* (*ACSR*) — These conductors are made up of a galvanized steel core surrounded by stranded aluminium wires. The principal advantages of these conductors are high tensile strength, light weight giving small sags, longer spans and much higher corona limit due to bigger diameters. The principal disadvantage is that larger diameters increase the pole loading due to windage necessitating heavier poles. Their ultimate strength ranges from 125 percent for small size to about 180 percent for large sizes as compared with 100 percent of copper.

6.1.1.1 In coastal, industrial and other corrosive atmospheres it is preferable to coat the steel core with suitable corrosion preventive grease to mitigate galvanic action and galvanic corrosion.

6.1.2 *All Aluminium Conductors* — These are stranded conductors made of aluminium wires. These conductors are strong, durable, light weight and possess high conductivity. The average ultimate strength of stranded aluminium is about 65 percent of stranded copper. They need special care in handling. All aluminium conductors cannot take much tension as compared to ACSR conductors and, therefore, the span length gets restricted.

*Specification for aluminium conductors for overhead transmission purposes:

Part 1 Aluminium stranded conductors (*second revision*).

Part 2 Aluminium conductors, galvanized steel reinforced (*second revision*).

Part 3 Aluminium conductors, aluminized steel reinforced (*second revision*).

Part 4 Aluminium alloy stranded conductors (aluminium-magesium-silicon type) (*second revision*).

6.1.3 *Galvanized Steel Conductors* — These are stranded conductors made of galvanized steel wires. The principal disadvantage with these conductors is their relatively short life, which is about 16 years in rural areas and about 9 years in industrial areas and during which period iron insulator binders require frequent renewal owing to rapid corrosion. They are easy to handle, have greater strength and are cheaper.

6.1.4 *Copper Conductors* — Copper conductors are the oldest and most commonly used overhead line conductors. These are the basis of comparison for all other types which are rated according to their copper equivalent current carrying capacity. The principal advantages are high conductivity, long life, simplicity of jointing, less windage effect due to small diameters and thus lighter poles and high scrap value. The principal disadvantages are low line tensions and hence large sags, short spans and greater number of poles.

6.1.5 Physical and electrical properties of ACSR and all aluminium conductors and copper conductors shall be in accordance with appropriate parts of IS : 398* and IS : 282-1982† respectively.

6.2 Earthing Conductors — There are two methods of earthing associated with overhead lines for reducing the damage to life and plant in case the protection system fails to operate or in case of lightning hazards. They are:

a) Continuous overhead earth wires; and

b) Individual earthing of each pole.

6.2.1 Continuous overhead earth wire is more commonly used and its main functions are :

a) to form a continuous and low resistance return path for earth leakage currents necessary for the operation of protective systems, and

b) to reduce the effects of induced voltage in adjacent communication circuits under fault conditions.

6.2.1.1 Individual earthing of poles does not provide a continuous return path for earth currents although it reduces the effects of induced voltage in adjacent communication circuits under fault conditions.

6.2.2 Galvanized steel wires are very commonly used as earthing conductors. The size of the wire depends upon the span and the expected fault current.

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*Specification for aluminium conductors for overhead transmission purposes:

Part 1 Aluminium stranded conductors (*second revision*).
Part 2 Aluminium conductors, galvanized steel reinforced (*second revision*).
Part 3 Aluminium conductors, aluminized steel reinforced (*second revision*).
Part 4 Aluminium alloy stranded conductors (aluminium-magnesium-silicon type) (*second revision*).

†Specification for hard-drawn copper conductors for overhead power transmission. (*second revision*).

6.2.3 For earthing of overhead power lines, reference is also invited to IS : 3043-1966*, particularly to **18** of this code.

6.3 Choice of Conductors — The physical and electrical properties of different conductors shall be in accordance with relevant Indian Standards. All conductors shall have a breaking strength of not less than 350 **kg.** However, for low voltage lines with spans less than 15 m and installed either on owner's or consumer's premises, conductors with breaking strength of not less than 140 kg may be used.

6.3.1 The choice of the size of conductors for a line mainly depends upon the following:

a) Power to be transmitted,
b) Length of the line,
c) Line voltage,
d) Permissible voltage regulation, and
e) Mechanical strength.

6.3.2 In accordance with the Indian Electricity Rules voltage variation for low voltage lines should not be more than ± 6 percent and for high voltage lines should not be more than + 6 percent to −9 percent.

6.3.3 The kW-km that can be transmitted at a particular voltage with particular type of conductors are given in Tables 1 and 2.

6.3.4 Power loss and voltage drop of a short line may be calculated by the following formulae:

6.3.4.1 *Power loss*

$$W = I^2R$$

where

W = power loss per km per conductor in watts,
I = line current in amperes, and
R = ac resistance per km per conductor of the line in ohms.

6.3.4.2 *Voltage drop*

a) For single-phase lines

$U = 2\ (IR \cos\phi + IX \sin\phi)$, and

b) For three-phase lines

$U = \sqrt{3}\ (IR \cos\phi + IX \sin\phi)$

*Code of practice for earthing.

TABLE 1 kW-km FOR 415/240 VOLTS LINES WITH 5 PERCENT VOLTAGE REGULATION (CONDUCTOR MATERIAL — ALL ALUMINIUM AND COPPER)

(*Clause* 6.3.3)

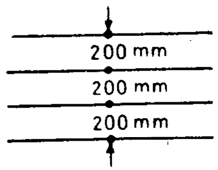
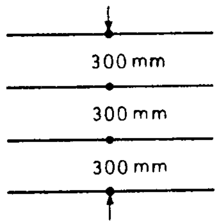
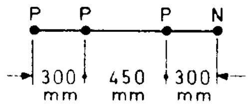
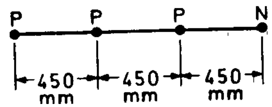
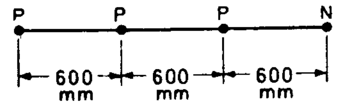
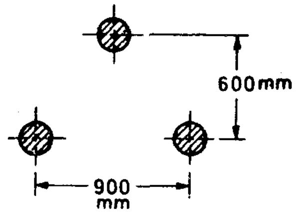
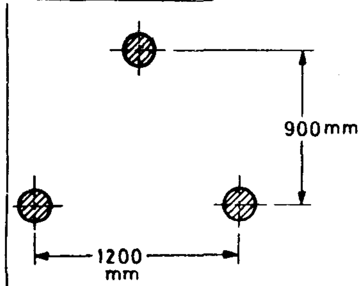
Area of Conductors mm²	kW-km at 80 Percent Power Factor for Various Configurations															kW-km at 100 Percent Power Factor		
																		
	Equivalent Spacing 255 mm			Equivalent Spacing 385 mm			Equivalent Spacing 470 mm			Equivalent Spacing 575 mm			Equivalent Spacing 765 mm					
	54·4°C	60°C	65·6°C	54·4°C	60°C	65·6°C	54·4°C	60°C	65·6°C	54·4°C	60°C	65·6°C	54·4°C	60°C	65·6°C	54·4°C	60°C	65·6°C
All Aluminium 13	4·511	4·437	4·333	4·463	4·389	4·316	4·439	4·366	4·295	4·416	4·344	4·274	4·384	4·313	4·242	5·164	5·066	4·971
16	5·491	5·401	5·316	5·420	5·333	5·248	5·383	5·298	5·214	5·351	5·266	5·184	5·303	5·219	5·139	6·463	6·339	6·220
20	6·378	6·275	6·177	6·281	6·186	6·087	6·233	6·135	6·040	6·188	6·991	5·998	6·124	6·029	5·938	7·696	7·546	7·405
25	8·238	8·108	7·992	8·077	7·953	7·812	7·998	7·876	7·767	7·924	7·805	7·697	7·820	7·702	7·599	10·493	10·284	10 099
30	9·711	9·559	9·434	9·492	9·355	9·226	9·381	9·249	9·123	9·281	9·151	9·028	9·136	9·011	8·892	12·907	12·659	12·423
Copper 8·5	2·992	2·940	2·890	2 969	2·919	2·871	2·960	2·910	2·860	2·948	2·898	2·852	2·934	2·886	2·837	3·299	3·238	3·171
14	4·469	4·397	4·326	4·422	4·350	4·281	4·398	4·328	4·258	4·676	4·307	4·337	4·344	4·274	4·208	5·160	5·063	4·968
16	6·124	6·029	5·935	6·035	5·943	5·852	5·992	5·901	5·810	5·948	5·860	5·769	5·889	5·802	5·715	7·438	7·298	7·160
25	8·348	8·225	8·111	8·185	8·068	7·958	8·103	7·987	7·879	8·027	7·913	7·807	7·920	7·809	7·706	10·865	10·659	10·467
40	10·905	10·758	10·617	10·626	10·486	10·351	10·488	10·353	10·221	10·364	10·231	10·103	10·186	10·057	9·933	15·390	15·099	14·819

TABLE 2 kW-km FOR 11 kV LINES WITH 12·5 PERCENT VOLTAGE REGULATION (CONDUCTOR MATERIAL — ACSR AND COPPER)

(*Clause* 6.3.3)

Size of Conductor		kW-kM at 80 Percent Power Factor for Various Configurations						kW-km at 100 Percent Power Factor		
										
		Equivalent Spacing 810 mm			Equivalent Spacing 1 145 mm					
		54·4°C	60°C	65·6°C	54·4°C	60°C	65·6°C	54·4°C	60°C	65·6°C
ACSR	13 mm^2	8 216	8 082	7 952	8 155	8 023	7 894	9 662	9 477	9 300
	16 mm^2	9 967	9 809	9 659	9 873	9 719	9 571	12 128	11 896	11 674
	20 mm^2	11 618	11 436	11 269	11 491	11 312	11 148	14 592	14 309	14 045
	25 mm^2	14 634	14 426	14 223	14 420	14 231	13 989	19 520	19 151	18 795
	30 mm^2	17 336	17 093	16 867	17 054	16 818	16 600	24 438	23 957	23 517
Copper	4·25 mm dia	8 193	8 068	7 937	8 130	8 002	7 878	9 756	9 571	9 394
	4·75 mm dia	11 103	10 939	10 773	10 982	10 821	10 660	14 061	13 798	13 538
	16 mm^2	9 944	9 788	9 642	9 851	9 698	9 553	12 250	12 014	11 793
	35 mm^2	17 062	16 827	16 608	16 780	16 552	16 341	25 512	24 029	23 586

where

U = voltage drop per km in volts,

I = line current in amperes,

R = ac resistance per km per conductor of the line in ohms,

ϕ = angle of lag/lead in degrees, and

X = reactance per km per conductor of the line in ohms.

6.4 Spacing of Conductors

6.4.0 The configuration of conductors is a matter of choice and no definite recommendations can be given in this code.

6.4.1 To have proper insulation clearance, in order to avoid trouble due to birds and to avoid conductors clashing due to wind, it is very essential that conductors in an overhead power line are adequately spaced.

6.4.2 There are no fixed rules for spacing arrangement of overhead line conductors. However, the following formula gives an economical spacing of conductors:

$$D = 500 + 18\,U + \frac{L^2}{50}$$

where

D = spacing in mm,

U = phase-to-phase voltage in kV, and

L = span length in m.

7. SAG-TENSION

7.1 In practice, for overhead line design, the general theory for sag-tension is based on the fact that if a flexible wire of uniform weight is suspended at two points at the same level, it sags and assumes the shape of a catenary curve. For short spans normally adopted for transmission and distribution lines the catenary is very nearly a parabola and hence the sag is calculated by the following formula:

$$S = \frac{wl^2}{8T}$$

where

S = sag in m,

w = weight of loaded conductor in kg per metre run,

l = span length in metres, and

T = maximum working tension in conductor in kg.

7.1.1 For supports at different levels, the distance l' of the point at which the maximum sag s which occurs from taller or shorter support is given by

$$l' = \frac{1}{2} + \frac{Th}{Wl}, \text{ and}$$

$$\text{Sag } s = \frac{wl'^2}{2T}$$

where

l' = span length in metres,

h = difference in level between the supports in metres,

w = weight of loaded conductor in kg per metre run, and

T = maximum working tension in conductor in kg.

7.2 For calculating sag and tension, it is necessary to consider two sets of loading conditions:

a) Maximum wind pressure and minimum temperature, and

b) Still air condition with no ice on the conductors at maximum temperature in the region.

NOTE 1 — For the purpose of this code, weight of ice has not been taken into consideration. Where ice loading is encountered, it should be taken into account. The thickness of ice should be taken based on local conditions.

NOTE 2 — Guidance can be taken from IS : 875-1964* for reduction factor for design wind pressure for towers up to 30 m height.

7.2.1 The wind pressure maps and temperature maps are given in Fig. 1 and Fig. 2 respectively.

7.3 It is necessary that loading factors should be determined for both the above conditions.

7.3.1 Loading factor for wind is given by:

$$q_1 = \sqrt{\frac{w^2 + w_1^2}{w}}$$

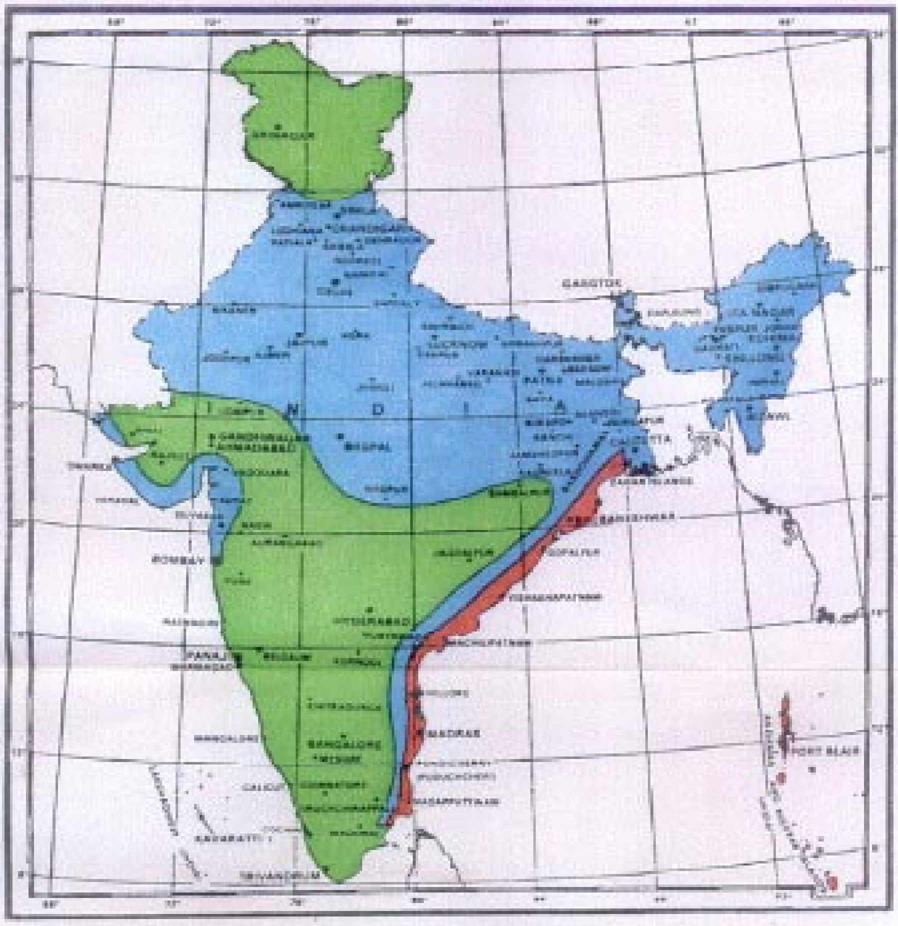
where

q_1 = loading factor,

w = weight of unloaded conductor in kg per metre run, and

w_1 = wind load on conductor in kg/m.

*Code of practice for structural safety of building : Loading standards (*revised*).



The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate base line. Based upon Survey of India map with the permission of the Surveyor General of India.

NOTE 1 — For purposes of this map, a short duration wind is that which lasts only for a few minutes, generally less than 5 minutes.

NOTE 2 — The relationship between wind pressure and velocity is $p = KV^2$ where p is the pressure, V is the velocity and K is a coefficient, the value of which depends on a number of factors, such as the wind speed, the type, proportion and shape of structure and the temperature of air. In the preparation of this basic wind pressure map, a value of 0·006 has been assumed for K and p is expressed in kg/m^2 and V in km/h.

NOTE 3 — The basic wind pressures for the zones shown in the map shall be as given below:

ZONE	PRESSURES IN kg/m^2 UP TO A HEIGHT OF 30 m ABOVE THE MEAN RETARDING SURFACE	PRESSURES IN kg/m^2 AT A HEIGHT (EXPRESSED IN METRES) OF									
		35	40	45	50	60	70	80	100	120	150
	100	104	105	108	111	115	118	122	127	132	138
	150	156	158	163	167	172	177	183	191	198	207
	200	208	210	217	222	230	236	244	254	264	276

(For intermediate heights interpolated values may be adopted)

NOTE 4 — The basic wind pressures indicated above are the maximum ever likely to occur in the respective areas, under fully exposed conditions. In the case of mountainous areas, the values indicated above should be modified according to the local conditions because the surface wind is known to depend markedly on the local topography, etc.

NOTE 5 — Responsibility for the correctness of internal details rests with the publishers.

FIG. 1 BASIC MAXIMUM WIND PRESSURE MAP OF INDIA, INCLUDING WINDS OF SHORT DURATION AS IN SQUALLS

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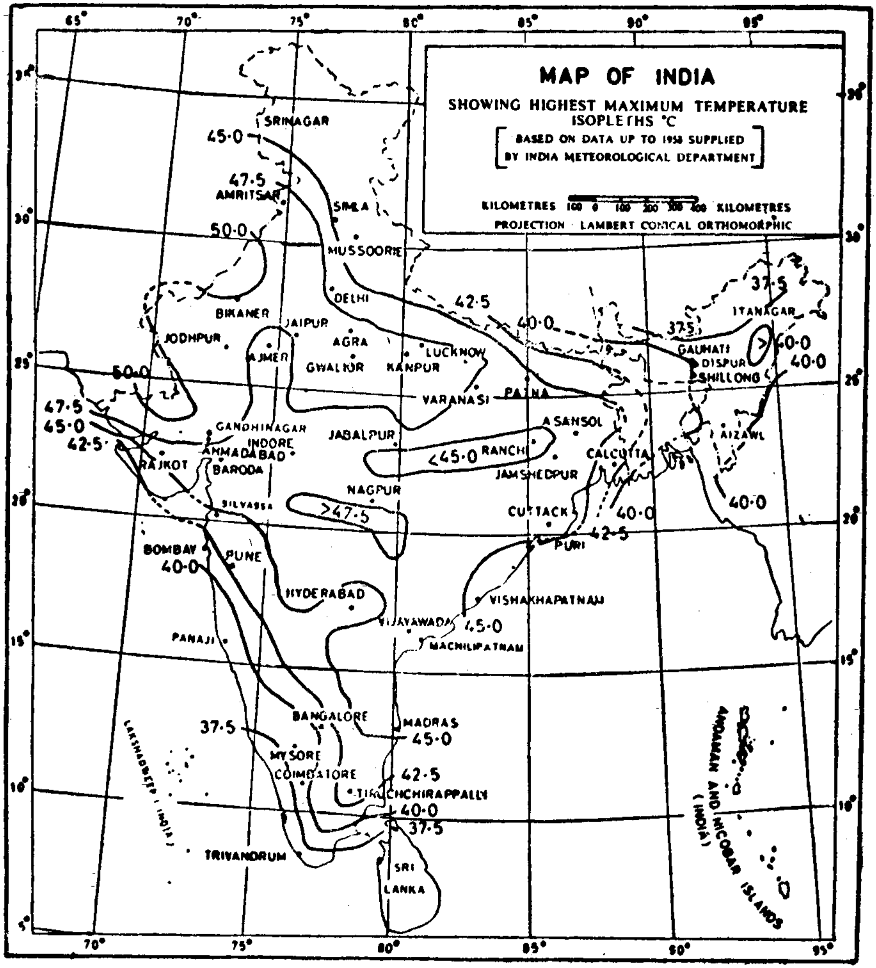

FIG. 2 CHART SHOWING HIGHEST MAXIMUM TEMPERATURE

The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate base line.

Based upon Survey of India map with the permission of the Surveyor General of India,

Responsibility for the correctness of internal details rests with the publishers.

7.3.1.1 Wind load is given by:

$$w_1 = \frac{2}{3} \times \frac{d}{1\,000} P$$

where

d = diameter of conductor in mm, and

P = wind pressure in kg/m^2.

7.3.2 Loading factor in steel air is $q_2 = 1$.

7.3.3 Different wind pressures are assumed for design purposes for different parts of the country and are given in the map in Fig. 1.

7.4 Sag at Worst Load Conditions of Wind

Let T_1 = maximum allowable tension in kg/m conductor at temperature t_1°C, and

l = span length in metres,

then the sag at worst loading condition is given by:

$$s = \frac{q_1\, w\, l^2}{8\, T_1}$$

7.5 Sag and Tension in Conductor Under Still Air Conditions

7.5.1 Since conductors will be erected under still air conditions at a temperature t_2 °C, it is essential that the erection tension should be such that when loading conditions subsequently occur, there shall be no infringement on the factor of safety. The factor of safety shall be in accordance with Rule 76 of Indian Electricity Rules, 1956.

7.5.2 The tension T_2 in the conductor at temperature t_2 °C is determined from the following formula:

$$T_2^2 \left[T_2 - (K - \alpha t \lambda) \right] = \frac{l^2 w^2 q_2^2 \lambda}{24}$$

where

T_2 = tension in conductor in kg at erection temperature t_2 °C,

E = modulus of elasticity in kg/cm^2,

A = area of conductor in cm^2,

α = coefficient of linear expansion per degree C ,

t = difference in temperature between the two sets of loading conditions = $(t_2 - t_1)$ °C,

$K = T_1 - \dfrac{l^2 w^2 q_1^2 \lambda}{24\, T_1^2}$, and

$\lambda = EA$.

7.5.3 After determining the value of T_2 in accordance with **7.5.2**, the sag may be calculated as follows:

$$s = \frac{w\, l^2}{8\, T_2}$$

7.6 An example of the calculation of sag and tension is given in Appendix A.

7.7 Recommended Span Lengths — The recommended span lengths for lines up to 11 kV are 45, 60, 65, 75, 90, 105 and 120 metres.

7.8 For 11 kV lines using suspension insulators, sag is calculated after determining the ruling span.

7.8.1 *Ruling (Equivalent) Span* — For erecting an overhead line all the spans cannot be kept equal because of the profile of the land and proper clearance considerations. If this were done then adjustments of tensions would be necessary in adjacent spans since any alteration in temperature and loading would result in unequal tension in the various spans. This is obviously impracticable as a constant tension must be applied at the tensioning position and this constant tension must be uniform throughout the whole of the section. With suspension insulators the tension unequalities would be compensated by string deflections but for post or pin insulators these inequalities would have to be taken by the binders which is not desirable. Therefore, a constant tension is calculated which will be uniform throughout the section. For calculating this uniform tension we choose an equivalent span for the whole length of the line. The ruling span is then calculated by the following formulae:

$$L_R = \sqrt{\frac{L_1^3 + L_2^3 + L_3^3 + \dots\dots\dots\dots}{L_1 + L_2 + L_3 + \dots\dots\dots\dots}}$$

where

L_R = ruling span, and

L_1, L_2, ... etc = different spans in a section.

Having determined the ruling span and basic tension, the sag may be calculated by the following formula:

$$S = \left(\frac{\text{actual span}}{\text{ruling span}} \right)^2 \times S_R$$

where

S = sag for actual span, and

S_R = sag for ruling span.

NOTE — For ready reference tensions may be calculated for different sizes of conductors for different span lengths and at different temperatures and plotted as sag-tension charts.

8. CLEARANCES

8.0 Clearances shall be in accordance with Indian Electricity Rules.

8.1 Minimum clearances for any conductor of an overhead line from ground and buildings at different places shall be as given below:

	For Low and Medium Voltage Lines	*For High Voltage Lines*
	m	m
a) Minimum height of any conductor of an overhead line across any street	5·8	6·1
b) Minimum height of any conductor of an overhead line along any street	5·5	5·8
c) Minimum height of any conductor (bare) of an overhead line erected elsewhere	4·6	4·6
d) Minimum height of any conductor (insulated) of an overhead line erected elsewhere	4·0	4·0
e) Minimum clearance of overhead line conductor from buildings	2·5 (vertical) 1·2 (horizontal)	3·7 (vertical) 1·2 (horizontal)

9. FACTORS OF SAFETY

9.1 Factors of safety shall be in accordance with Rule 76 of Indian Electricity Rules.

10. CROSS ARMS

10.1 Cross arms may be either of steel or wood.

10.1.1 *Steel Cross Arms* — Steel cross arms shall be angle or channel sections of steel in accordance with appropriate parts of IS : 808*.

10.1.2 *Wooden Cross Arms* — Wooden cross arms shall conform to IS: 2203-1976†.

*Specification for dimensions for hot-rolled steel sections.
†Specification for wooden cross arms (*first revision*).

11. POLES

11.1 Good poles chosen with regard to local conditions and requirements are decisive factor in ensuring continuity of service, long life of line and low maintenance costs.

11.2 Usually steel, wood, reinforced concrete or prestressed concrete poles are used for overhead power lines up to 11 kV. Although all these types may be used, wood poles are most economical and should be commonly used in rural areas. Details of different types of poles are described in **12** to **15**.

12. WOOD POLES

12.1 Wood poles shall conform to IS : 876-1970* and IS : 6056-1970† and shall be designed in accordance with IS : 5978-1970‡.

12.2 Classification — Based upon the average ultimate strength of standard clear specimen poles, without stays, of representative species of three groups of timber, that is, sal, teak and chir, having minimum top circumference as specified in Table 2 of IS : 5978-1970‡ and Table 1 of IS : 6056-1970† wood poles shall be grouped under seven strength classes, as given in Table 3.

12.3 Dimensions of Poles — The dimensions of the poles shall be selected from those given in Table 2 of IS : 5978-1970‡ and Table 1 of IS : 6056-1970†. For calculated sizes of intermediate lengths the next higher standard size shall be selected.

12.4 Design — Wood poles shall be designed as simple cantilevers except when used as struts, cross arms of braces. The design of wood poles shall be based on the values of modulus of rupture in bending in green condition, that is, above a moisture content of 25 percent. For evaluating the strength of a full pole, reference should be made to IS : 1900-1974§. The method of jointing and other requirements of utilizing short length for jointed poles shall be as given in **11** of IS : 6056-1970†. For the purposes of design of wood poles the strength values of different species of timber in their green condition may be taken from Appendix A of IS : 876-1970* and IS : 6056-1970†. In the design and erection of poles, it is important that most of the visible defects are, as far as possible, farthest away from points of maximum stress.

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*Specification for wood poles for overhead power and telecommunication lines (*second revision*).

†Specification for jointed wood poles for overhead power and telecommunication lines.

‡Code of practice for design of wood poles for overhead power and telecommunication lines (*revised*).

§Methods of tests for wood poles (*first revision*).

TABLE 3 CLASSIFICATION OF WOOD POLES

(*Clause* 12.2)

Class	Ultimate Breaking Load	
	Equal to and Above kg	Less Than kg
1	1 350	—
2	1 100	1 350
3	850	1 100
4	700	850
5	550	700
6	400	550
7	300	400

The above loads are assumed to be applied at 60 cm from the top of the poles, These classes shall apply to all species given in IS : 876-1970*.

NOTE — The strength of poles is determined by calculating the breaking load at the critical cross section which occurs (a) at the ground line, or (b) at the point where the diameter of pole is equal to 1·5 times the diameter at the point of application of the load or at the point of occurrence of the resultant load, if this value is less than the ground line diameter.

*Specification for wood poles for overhead power and telecommunication lines (*second revision*).

12.4.1 *Design Procedure* — Wood poles shall be designed in accordance with **7** and **8** of IS : 5978-1970*. The factor of safety, however, to be adopted for the design shall be 3·0.

13. STEEL TUBULAR POLES

13.1 Steel tubular poles shall conform to IS : 2713 (Parts 1 to 3)-1981†.

13.2 Dimensions of Poles — The dimensions of tubular poles generally used for overhead lines shall be as given in Tables 1 and 2 of IS : 2713 (Parts 1 to 3)-1981† for stepped and swaged poles respectively.

13.3 Selection of Poles — Poles shall be selected in accordance with IS : 2713 (Parts 1 to 3)-1981†.

14. PRESTRESSED CEMENT CONCRETE (PCC) POLES

14.1 Prestressed cement concrete (PCC) poles shall conform to IS : 1678 - 1978‡.

*Code of practice for design of wood poles for overhead power and telecommunication lines.

†Specification for tubular steel poles for overhead power lines (*second revision*).

‡Specification for prestressed concrete poles for overhead power, traction and telecommunication lines (*first revision*).

14.2 Dimension of Poles — Dimensions of PCC poles used for overhead lines shall be as given in Tables 1 and 2 of IS : 1678-1978*.

14.3 Selection of Poles — Prestressed cement concrete poles shall be selected in accordance with method described in Appendix A of IS : 785-1964†.

15. REINFORCED CEMENT CONCRETE (RCC) POLES

15.1 Reinforced cement concrete (RCC) poles shall conform to IS : 785-1964†.

15.2 Dimensions of Poles — Dimensions of RCC poles used for overhead lines shall be as given in Tables 1 and 2 of IS : 785-1964†.

15.3 Selection of Poles — RCC poles shall be selected in accordance with Appendix A of IS : 785-1964†.

16. FABRICATED STEEL STRUCTURE

16.1 Fabricated steel structure, when used, shall be subjected to type tests to ensure that factor of safety is equivalent or better than that of steel tabular poles.

17. EARTHING

17.1 Earthing associated with overhead power lines shall be done in accordance with IS : 3043-1966‡.

18. MATERIAL FOR FASTENERS

18.1 Bolts and Nuts — Bolts and nuts shall conform to IS : 6639-1972§. The mechanical properties shall conform to property class 4·6 and class 4 of IS : 1367-1967|| for bolts and nuts respectively.

18.2 Washers — Washers shall conform to IS : 2016-1967¶. Heavy washers shall conform to IS : 6610-1972**. Spring washers shall conform IS : 3063-1972††.

18.3 Galvanizing — Bolts and other fasteners shall be galvanized in accordance with IS : 5358-1969‡‡ galvanizing of the members of the tower shall conform to IS : 4759-1979§§ and spring washers shall be galvanized in accordance with IS : 1573-1970||||.

*Specification for prestressed concrete poles for overhead power, traction and telecommunication lines (*first revision*).

†Specification for reinforced concrete poles for overhead power and telecommunication lines (*revised*).

‡Code of practice for earthing.

§Specification for hexagon bolts for steel structures.

||Technical supply conditions for threaded fasteners (*first revision*).

¶Specification for plain washers (*first revision*).

**Specification for heavy washers for steel structures.

††Specification for spring washers for bolts, nuts and screws (*first revision*).

‡‡Specification for hot-dip galvanized coatings on fasteners.

§§Specifiation for hot-dip coatings on structural steel and other allied products.

||||Specification for electroplated coatings for zinc on iron and steel (*first revision*).

APPENDIX A

(*Clause* 7.6)

CALCULATION OF SAG AND TENSION

A-1. CONDITIONS

A-1.1 An example of sag and tension calculation for a conductor of following physical properties is given in **A-2**. The loading conditions, span length and the factor of safety are also given below:

Conductor material	ACSR
Conductor size	6/1/2·11
Overall dia of conductor (d)	$3 \times 2{\cdot}11 = 6{\cdot}33$ mm
Breaking strength of conductor	770 kg
Weight of conductor (w)	0·085 kg/m
Modulus of elasticity (E)	$0{\cdot}809 \times 10^6$ kg/cm^2
Coefficient of linear expansion (α)	$18{\cdot}99 \times 10^{-6}$ per deg C
Wind pressure (P)	75 kg/m^2
Span length (l)	45 m
Factor of safety under maximum loading condition	2
Factor of safety at 32° C and still air	4

A-2. CALCULATIONS

A-2.1 Area of Conductor (A)

Area of one strand [from Tables 1 and 2 of IS : 398 (Part 2)- 1976*] $= 3{\cdot}497$ mm^2

$$\text{Therefore } A = 7 \times \frac{3{\cdot}497}{100} = 0{\cdot}244\,79 \text{ cm}^2$$

A-2.2 Wind Load (w_1) $= \frac{2}{3} \cdot d.p$

$$\frac{2}{3} \times 75 \times \frac{6{\cdot}33}{1\,000} = 0{\cdot}316\,5 \text{ kg/m}$$

A-2.3 Loading Factor (q_1) $= \frac{\sqrt{w_1^2 + w^2}}{w}$

*Specification for aluminium conductors for overhead power transmission purposes: Part 2 Aluminium conductors, galvanized steel reinforced (*second revision*).

$$= \frac{\sqrt{0.316\,5^2 + 0.085^2}}{0.085} = 3.855\,5$$

A-2.4 Sag and Tension — Tension T_2 at 32°C and still air is given by:

$$T_2^2 [T_2 - (K - \alpha t \lambda)] = \frac{l^2 q_2^2 w^2 \lambda}{24}$$

$$\text{or } T_2^2 \left[T_2 - \left\{ \left(T_1 - \frac{l^2 w^2 q_1^2 \lambda}{24\ T_1^2} \right) - \alpha t \lambda \right\} \right] = \frac{l^2 q_2^2 w^2 \lambda}{24}$$

Maximum allowable tension $T_1 = \frac{770}{2} = 385$ kg

$$T_2^2 \left[T_2 - \left\{ \left(385 - \frac{(45)^2 \times (0.085)^2 (3.855\,5)^2 \times 0.809 \times 10^6 \times 0.244\,79}{24 \times (385)^2} \right) - 18.99 \times 10^{-6} \times (32 - 5) \times 0.809 \times 10^6 \times 0.244\,79 \right\} \right]$$

$$= \frac{(45)^2 \times 1 \times (0.085)^2 \times 0.809 \times 10^6 \times 0.244\,79}{24}$$

Therefore $T_2 = 273.0$ kg, and

Therefore factor of safety at 32°C and still air $= \frac{770}{273.0} = 2.82$

This factor of safety is less than 4.

So we take maximum allowable tension $T_2 = \frac{770}{4} = 192.5$ kg

Therefore $(192.5)^2 [192.5 - (K - \alpha t \lambda)] = \frac{l^2 w^2 q_2^2 \lambda}{24}$

or $(192.5)^2 [192.5 - \{ K - 18.99 \times 10^{-6} \times (32 - 5) \times 0.809 \times 10^6 \times 0.244\,79 \}]$

$$= \frac{(45)^2 \times (0.085)^2 \times 1 \times 0.244\,79 \times 0.809 \times 10^6}{24}$$

Therefore $K = 297.3$ kg

But $K = T_1 - \frac{l^2 w^2 q_1^2 \lambda}{24\ T_1^2}$

or $297.3 = T_1 - \frac{(45)^2 (0.085)^2 (3.855\,5)^2 \times 0.809 \times 10^6 \times 0.244\,79}{24\ T_1^2}$

$$= T_1 - \frac{1.794\,5 \times 10^6}{T_1^2}$$

or $T_1^2 [T_1 - 297{\cdot}3] = 1{\cdot}794\,5 \times 10^6$

or $T_1 = 309$ kg, and

Therefore factor of safety under worst condition $= \frac{770}{309} = 2{\cdot}49$

This is more than 2 and, therefore, the design is satisfactory.

Sag at 32°C and still air $= \frac{wl^2}{8\,T_2}$

$$= \frac{(0{\cdot}085) \times (45)^2}{8 \times 192{\cdot}5} = 11{\cdot}18 \text{ cm.}$$

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TO
IS 5613 (Part 1 / Sec 1) : 1985 CODE OF PRACTICE FOR DESIGN, INSTALLATION AND MAINTENANCE OF OVERHEAD POWER LINES

PART 1 LINES UP TO AND INCLUDING 11 kV

Section 1 Design

(First Revision)

(*Page* 9, *Table* 1, *Title*) — Substitute '6 percent voltage regulation' *for* '5 percent voltage regulation'.

(*Page* 10, *Table* 2, *Title*) — Substitute '+6 percent to -9 percent voltage regulation' *for* '12.5 percent voltage regulation'.

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