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 ijirset@gmail.com

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Lightning Protection Calculation for Industrial Buildings as per IEC 62305

Pradeep Sethi¹, Neerav Gupta², Vineet Sharma³

Design Engineer Fluor Daniel Gurgaon, India¹

Principal Design Engineer Fluor Daniel Gurgaon, India²

Senior Engineer Fluor Daniel Gurgaon, India³

ABSTRACT: This paper explains the process of lightning protection as per IEC-62305 Part-1/2/3/4. IEC / BS EN 62305 provides general principles, risk management, protection for physical damage to structures and life hazards, protection against electrical and electronic systems in the structures. Methodology for risk analysis is provided in BS EN 62305-2-2012 to evaluate the need of lightning protection. If the risk for building/structure is above the tolerable limit as per Table 4 of 62305-2 as below, then lightning protection shall be provided.

Type of Loss	R_T
L1 Loss of human life or permanent injuries	10^{-5}
L2 Loss of service to the public	10^{-3}
L3 Loss of cultural heritage	10^{-4}

Details and procedure for the evaluation of risk for industrial buildings is presented in the following sections

KEYWORDS: Lightning Protection, IEC 62305

1. INTRODUCTION

Lightning protection is provided to facilitate low impedance lightning discharge path to earth. Lightning strike cannot be prevented, however adequate lightning protection may be provided to prevent / minimize the damage to building, equipment and persons inside the building.

Before BS EN/IEC 62305, BS 6651 was the standard used to design the lightning protection. In the year 2006, BS EN/IEC 62305 was introduced and for some time both the standards i.e. BS EN/IEC 62305 and BS 6651 were in practice but from 2008 BS EN/IEC 62305 (Part 1/2/3/4) is the most followed standard in IEC world for lightning protection.

BS EN/IEC 62305 has four parts which addresses various design aspects of lightning Protection:

BS EN 62305-1: **General Principles** provides the general explanatory details for protection against lightning.

BS IEC 62305-2: **Risk Management** provides methodology for evaluation of risk to determine the need for protection, the economic benefits of installing protection measures and the selection of adequate protection measures.

BS EN 62305-3: **Physical Damage to Structure and Life Hazard** provides design and installation methods to reduce physical damage and life hazard in a structure.

BS EN 62305-4: **Electrical and Electronic Systems** within Structures, provides design and installation methods to reduce the adverse impact of lightning on electrical and electronic systems within structures. This part is mainly applicable for the structures which have Electrical/Electronic devices e.g. Substation and satellite control rooms.



This paper outlines the following for industrial buildings such as substations and control rooms :

1. Risk assessment Methodology.
2. The input parameters required to perform the risk assessment.
3. Risk assessment calculation.
4. Selection of lightning protection system level.

II. METHODOLOGY

For an industrial building to be protected, the following shall be included in the risk assessment.

- The industrial building itself
- Installations and contents in the industrial building
- Persons in the industrial building

Source of damage, Type of damage and loss shall be calculated as per clause 4.1 of IEC 62305-2.

Source of damage

In order to determine the risk, four main sources of damage are to be considered :

S1	flashes to a structure
S2	flashes near a structure
S3	flashes to a line
S4	flashes near a line

Parameter	Denomination	IEC 62305-2 clause reference
Average annual number of dangerous events due to flashes		
N_D	– to the structure	A.2
N_M	– near the structure	A.3
N_L	– to a line entering the structure	A.4
N_I	– near a line entering the structure	A.5
N_{DJ}	– to the adjacent structure	A.2
Probability that a flash to the structure will cause		
PA	– injury to living beings by electric shock	B.2
PB	– physical damage	B.3
PC	– failure of internal systems	B.4
Probability that a flash near the structure will cause		
PM	– failure of internal systems	B.5
Probability that a flash to a line will cause		
PU	– injury to living beings by electric shock	B.6
PV	– physical damage	B.7
PW	– failure of internal systems	B.8
Probability that a flash near a line will cause		
PZ	– failure of internal systems	B.9
Loss due to		
$LA = LU$	– injury to living beings by electric shock	C.3



Types of damage:

D1	injury to living beings by electric shock
D2	physical damage
D3	failure of electrical and electronic systems

Types of loss:

L1	loss of human life (including permanent injury)
L2	loss of service to the public
L3	loss of cultural heritage
L4	loss of economic value (structure, content, and loss of activity).

Composition of risk components

- R_1 : Risk of loss of human life
- R_2 : Risk of loss of service to the public
- R_3 : Risk of loss of cultural heritage
- R_4 : Risk of loss of economic value

Summary of risk components

Damage	Source of damage			
	S1	S2	S3	S4
D1	$RA = ND \times PA \times LA$		$RU = (NL + NDJ) \times PU \times LU$	
D2	$RB = ND \times PB \times LB$		$RV = (NL + NDJ) \times PV \times LV$	
D3	$RC = ND \times PC \times LC$	$RM = NM \times PM \times LM$	$RW = (NL + NDJ) \times PW \times LW$	$RZ = NI \times PZ \times LZ$

IEC 62305-2 provides the calculation methodology and values for the following parameters. Reference clauses are indicated below.

II. INPUT PARAMETERS REQUIRED FOR PERFORMING THE RISK ANALYSIS

To perform lightning risk assessment calculation for an industrial building the following input parameters shall be gathered.

1. The number of lightning flashes to ground per km² per year. This parameter is used to calculate the lightning ground flash density NG.

This information shall be considered in the following order of precedence :

- From project meteorological data/ geo technical information.
- Latest available meteorological record for a particular country.
- Figure NF.2 of BS EN 62305-2 provides map showing thunderstorm days per year throughout the world. Note: the information in the maps is based on world meteorological organization



records for 1955. Hence, latest meteorological data from project or of the particular country shall take precedence.

2. Industrial building dimensions such as total length, width and height to determine the collection area A_D .
3. Building construction material such as concrete, wood or brick shall be obtained.
4. Cable details for HV power line which has longest length from the building and its Installation type, cable construction with dimensions, withstand voltage of internal system (kV) shall be identified and available.
5. Cable details for communication line which has longest length from the building, installation type, cable construction with dimensions, withstand voltage of internal system (kV) shall be identified and available.
6. Number of persons in the building and total time of presence per year shall be identified and available.

III. RISK ASSESSMENT CALCULATION

A case study of risk assessment for an industrial building is considered below.

Consider an industrial building as a substation which houses HV & LV switchgears, motor control centres, uninterruptible power supply panels and batteries, auxiliary supply panels such as lighting panels, DC distribution panels.

As per meteorological data, average annual number of thunderstorm days for year 2012 to 2014 is tabulated below for some assumed location somewhere in Middle East.

Annual number of thunderstorm days	Year
23	2012
11	2013
9	2014

From the above the average annual number of thunderstorm days in a year is considered as 14.3.

Details of one largest length of HV power line & communication line entering the substation is considered as below.

HV Power line

Length (m)	2500
Installation	Buried
Shielding	Yes
Withstand voltage	15kV
Cable shielding resistance	$R_s \leq 1 \Omega/\text{km}$

Communication line

Length (m)	2650
Installation	Buried
Shielding	Yes
Withstand voltage	1 kV
Cable shielding resistance	Shielding not bonded.

Substation building is generally unmanned.



Human presence (hours per year) in unmanned substation greatly influence the result of the calculation. Hence, exact data of human presence (hours per year) to be considered in an industrial substation shall be obtained from client maintenance team.

For the purpose of this case study, the human presence in substation is considered as 20 hours per year.

The above indicated values are assumed typical and calculation values for a typical industrial building as per BS EN 62305-2 are considered in the calculation.

1. In general, the parameters which change in a project are industrial building dimensions. Calculations for two types of scenarios are considered.

aScenario 1

For substation building with height & width 10 meters constructed using concrete with length **up to 30 meters**.

b Scenario 2

For substation building with height & width 10 meters constructed using concrete with length **above 30 meters**



Data for substation building and its surroundings

Input parameter	Comment	Symbol	Value	Reference
Ground flash density (1/km ² /year)		N _G	1.43	NG ≈ 0,1 T _D
Location factor of structure	Structure surrounded by objects of the same height or smaller	C _D	0.5	Height of building is 10m, As per clause A 2.3 assumed there are "Structure surrounded by objects of the same height or smaller" at 3x10m radius. As per Table A.1
LPS	Structure not protected by LPS	P _B	1	IEC 62305-2, Table B.2
LPL for SPDs	No SPD	P _{EB}	1	IEC 62305-2, Table B.7
Mesh Width (Mtr)		w _{m1}	0	
Mesh Width (Mtr)		w _{m2}	0	
External spatial shield		K _{S1}	1	IEC 62305-2, Formula (B.5)

Data for the HV power lines - 11kV cable

Input parameter	Comment	Symbol	Value	Reference
Length (m)		L _L	2500	
Installation factor	Buried	C _I	0.5	IEC 62305-2, Table A.2
Line type factor	HV Power	C _T	0.2	IEC 62305-2, Table A.3
Environmental factor	Suburban	C _E	0.5	IEC 62305-2, Table A.4
Shielding, grounding, isolation	Shielded buried line, Shield bonded to the same bonding bar as equipment	C _{LD}	1	IEC 62305-2, Table B.4
		C _{LI}	0	IEC 62305-2, Table B.4
Structure connecting the power cable(m)	Main Substation	L _J	50	Figure A5
		W _J	10	
		H _J	11	



Location factor of adjacent structure	Structure surrounded by objects of the same height or smaller	C_D	0.5	Height of building is 10m, As per clause A 2.3 assumed there are "Structure surrounded by objects of the same height or smaller" at 3x10m radius. As per IEC 62305-2, Table A.1
Withstand voltage of internal system (kV)		U_W	15	
For HV 11kV cables $R_s \leq 1 \Omega/\text{km}$	Resulting parameters	K_{S4}	0.067	IEC 62305-2, Formula (B.7)
		P_{LD}	0.02	IEC 62305-2, Table B.8
		P_{LI}	0.1	IEC 62305-2, Table B.9

Data for the communication line or LV power line - 1KV control cable

Input parameter	Comment	Symbol	Value	Reference (Annexure "A" & "B")
Length (m)		L_L	2500	
Installation factor	Buried	C_I	0.5	IEC 62305-2, Table A.2
Line type factor	LV power, telecommunication or data line	C_T	1	IEC 62305-2, Table A.3
Environmental factor	Suburban	C_E	0.5	IEC 62305-2, Table A.4
Shielding, grounding, isolation	Shielded buried line	C_{LD}	1	IEC 62305-2, Table B.4
		C_{LI}	0	IEC 62305-2, Table B.4
Adjacent structure (m)	Main Substation	L_J	50	Figure A5
		W_J	10	IEC 62305-2, A2.5
		H_J	11	IEC 62305-2, A2.5
Location factor of adjacent structure	Structure surrounded by objects of the same height or smaller	C_D	0.5	Height of building is 10m, As per clause A 2.3 assumed there are "Structure surrounded by objects of the same height or smaller" at 3 x 10m radius. As per IEC 62305-2, Table A.1
Withstand voltage of internal system (kV)		U_W	1	IEC 62305-2, Table B.5



	Resulting parameters	K_{S4}	1	IEC 62305-2, Formula (B.7)
		P_{LD}	1	IEC 62305-2, Table B.8, "shielded whose shield is not bonded to the same bonding bar as equipment"
		P_{LI}	1	IEC 62305-2, Table B.9

Substation	No of persons	$n_z = n_t$	1	C.3; C.4
	Time of presence (Hours per year)	t_z	20	C.3; C.4

Factors for substation building

Input parameter	Comment	Symbol	Value	Reference
Type of floor	Concrete	r_t	0.01	IEC 62305-2, Table C.3
Protection against shock (flash to structure)	No protection measures	P_{TA}	1	IEC 62305-2, Table B.1
Protection against shock (flash to line)	Electrical insulation	P_{TU}	0.01	IEC 62305-2, Table B.6
Risk of fire	Low	r_f	0.001	IEC 62305-2, Table C.5
Fire protection	extinguishers, escape routes	r_p	0.5	IEC 62305-2, Table C.4
Internal spatial shield	None	K_{S2}	1	IEC 62305-2, Formula (B.6)
Input parameter	Comment	Symbol	Value	Reference
Internal wiring	Unshielded cable – no routing precaution in order to avoid loops	K_{S3}	1	IEC 62305-2, Table B.5
Coordinated SPDs	None	P_{SPD}	1	IEC 62305-2, Table B.3
Internal wiring	Unshielded cable – no routing precaution in order to avoid loops	K_{S3}	1	IEC 62305-2, Table B.5
Coordinated SPDs	None	P_{SPD}	1	IEC 62305-2, Table B.3
	No special hazard	h_z	1	IEC 62305-2, Table C.6



L1: Loss of human life	D1: All types	L_T	0.01	IEC 62305-2, Table C.2
	D2: Industrial, commercial	L_F	0.02	IEC 62305-2, Table C.2
	D3: Other parts	L_O	0.001	IEC 62305-2, Table C.2
L_A : Factor for persons in zone	$n_z / n_t \times t_z / 8760$	L_A	0.0023	
Substation dimensions (m)				
		W	10	
		H	10	

Collection areas of structure and lines		For length upto 30m		For length above 30m	
		Length > 30m	Length <= 30m	Reference Formula (62305-2)	Formula
	Symbol	Result m^2	Result m^2	Reference Formula (62305-2)	Formula
Structure	A_D	6926	5526	Clause A.2.1.1, IEC 62305-2 (A.2)	$A_D = L \times W + 2 \times (3 \times H) \times (L + W) + \pi \times (3 \times H)^2$
	A_M	845000	825000	IEC 62305-2 Clause A.3, (A.7)	$A_M = 2 \times 500 \times (L+W) + \pi \times 500^2$
Power line	$A_{L/P}$	100000	100000	IEC 62305-2 (A.9)	$A_{L/P} = 40 \times L_L$
	$A_{I/P}$	10000000	10000000	IEC 62305-2 (A.11)	$A_{L/P} = 4000 \times L_L$
	$A_{D/I/P}$	7879.46	7879.46	IEC 62305-2 (A.2)	$A_{D/I/T} = L_J \times W_J + 2 \times (3 \times H_J) \times (L_J + W_J) + \pi \times (3 \times H_J)^2$
Telecom line	$A_{L/T}$	100000	100000	IEC 62305-2 (A.9)	$A_{L/P} = 40 \times L_L$
	$A_{I/T}$	10000000	10000000	IEC 62305-2 (A.11)	$A_{L/P} = 4000 \times L_L$
	$A_{D/I/T}$	7879.46	7879.46	IEC 62305-2 (A.2)	$A_{D/I/T} = L_J \times W_J + 2 \times (3 \times H_J) \times (L_J + W_J) + \pi \times (3 \times H_J)^2$



Expected annual number of dangerous events

		Length > 30m	Length <= 30m		
	Symbol	Result m ²	Result m ²	Reference Formula	Formula
Structure	N _D	0.00495209	0.00395109	IEC 62305-2 (A.4)	$N_D = N_G \times A_{D/B} \times C_{D/B} \times 10^{-6}$
	N _M	1.20835	1.17975	IEC 62305-2 (A.6)	$N_M = N_G \times A_M \times 10^{-6}$
Power line	N _{L/P}	0.00715	0.00715	IEC 62305-2 (A.8)	$N_{L/P} = N_G \times A_{L/P} \times C_{I/P} \times C_{E/P} \times C_{T/P} \times 10^{-6}$
	N _{I/P}	0.715	0.715	IEC 62305-2 (A.10)	$N_{I/P} = N_G \times A_{I/P} \times C_{I/P} \times C_{E/P} \times C_{T/P} \times 10^{-6}$
	N _{D/I/P}	0.001126763	0.001126763	IEC 62305-2 (A.5)	$N_{D/I/P} = N_G \times A_{D/I/P} \times C_{D/I/P} \times C_{T/P} \times 10^{-6}$
Telecom line	N _{L/T}	0.00715	0.00715	IEC 62305-2 (A.8)	$N_{L/T} = N_G \times A_{L/T} \times C_{I/T} \times C_{E/T} \times C_{T/T} \times 10^{-6}$
	N _{I/T}	3.575	3.575	IEC 62305-2 (A.10)	$N_{I/T} = N_G \times A_{I/T} \times C_{I/T} \times C_{E/T} \times C_{T/T} \times 10^{-6}$
	N _{D/I/T}	0.005633814	0.005633814	IEC 62305-2 (A.5)	$N_{D/I/T} = N_G \times A_{D/I/T} \times C_{D/I/T} \times C_{T/T} \times 10^{-6}$
D1	L _A = L _U	2.28311e ⁻⁰⁷	2.28311e-07	IEC 62305-2 C.1	$r_t \times L_T \times n_z/n_t \times t_z/8760$
D2	L _B = L _V	2.28311e ⁻⁰⁸	2.28311e-08	IEC 62305-2 C.3	$r_p \times r_f \times h_z \times L_f \times n_z/n_t \times t_z/8760$
D3	L _C = L _M = L _W = L _Z	2.28311e ⁻⁰⁶	2.28311e-06		$L_o \times n_z/n_t \times t_z/8760$
	P _{MS}	0.004444444	0.004444444	IEC 62305-2 B.4	$P_{MS} = (K_{S1} \times K_{S2} \times K_{S3P} \times K_{S3T} \times K_{S4P} \times K_{S4T})^2$

Type of damage	Symbol	Z	Z	Formula	Reference
D1 Injury due to shock	P _A	1	1	$P_A = P_{TA} \times P_B$	IEC 62305-2 B.1
	P _{U/P}	0.0002	0.0002	$P_U = P_{TU} \times P_{EB} \times P_{LD} \times C_{LD}$	IEC 62305-2 B.8



	P_{UT}	0.01	0.01	$P_U = P_{TU} \times P_{EB} \times P_{LD} \times C_{LD}$	IEC 62305-2 B.8
D2 Physical damage	P_B	1	1		IEC 62305-2, Table B.2
	P_{VP}	0.02	0.02	$P_V = P_{EB} \times P_{LD} \times C_{LD}$	IEC 62305-2 B.9
	P_{VT}	1	1	$P_V = P_{EB} \times P_{LD} \times C_{LD}$	IEC 62305-2 B.9
	P_C	1	1	$P_C = P_{SPD} \times C_{LD}$	IEC 62305-2 B.2
D3 Failure of internal systems	P_M	0.004444444	0.004444444	$P_M = P_{SPD} \times P_{MS}$	IEC 62305-2 B.3
	P_{WP}	0.02	0.02	$P_W = P_{SPD} \times P_{LD} \times C_{LD}$	IEC 62305-2 B.10
	P_{WT}	1	1	$P_W = P_{SPD} \times P_{LD} \times C_{LD}$	IEC 62305-2 B.10
	P_{ZP}	0	0	$P_Z = P_{SPD} \times P_{LI} \times C_{LI}$	IEC 62305-2 B.11
	P_{ZT}	0	0	$P_Z = P_{SPD} \times P_{LI} \times C_{LI}$	IEC 62305-2 B.11

Type of damage	Formula	Length > 30m	Length <= 30m	Reference 62305-2
		Z	Z	
D1 Injury due to shock	$R_A = N_D \times P_A \times L_A$	$1.13061e^{-05}$	$9.02075e^{-06}$	Table 6
	$R_{Up} = (N_L + N_{DJ}) \times P_U \times L_U$	$3.77934e^{-13}$	$3.77934e^{-13}$	Table 6
	$R_{Ut} = (N_L + N_{DJ}) \times P_U \times L_U$	$2.91868e^{-11}$	$2.91868e^{-11}$	Table 6
D2 Physical damage	$R_B = N_D \times P_B \times L_B$	$1.13061e^{-10}$	$9.02075e^{-11}$	Table 6
	$R_{VP} = (N_L + N_{DJ}) \times P_V \times L_V$	$3.77934e^{-12}$	$3.77934e^{-12}$	Table 6
	$R_{VT} = (N_L + N_{DJ}) \times P_V \times L_V$	$2.91868e^{-10}$	$2.91868e^{-10}$	Table 6
D3 Failure of internal systems	$R_C = N_D \times P_C \times L_C$	$1.13061e^{-08}$	$9.02075e^{-09}$	Table 6
	$R_M = N_M \times P_M \times L_M$	$1.22613e^{-08}$	$1.19711e^{-08}$	Table 6
	$R_{WP} = (N_L + N_{DJ}) \times P_W \times L_W$	$3.77934e^{-10}$	$3.77934e^{-10}$	Table 6
	$R_{WT} = (N_L + N_{DJ}) \times P_W \times L_W$	$2.91868e^{-08}$	$2.91868e^{-08}$	Table 6



$R_{ZP} = N_I \times P_Z \times L_Z$	0	0	Table 6
$R_{ZT} = N_I \times P_Z \times L_Z$	0	0	Table 6

Summary- Risks

Type of Risk	Formula	Length > 30m	Length <= 30m	Tolerable risk R_T (As per clause 5.3 of 62305-2)
		Total Risk	Total Risk	
R_1 : risk of loss of a human life	$R_1 = R_{A1} + R_{B1} + R_{U1} + R_{V1}$	$1.1307e^{-05}$	$9.02117e^{-06}$	10^{-5}
		$R_1 > R_T$ for L1 hence lightning protection is required	$R_1 < R_T$ for L1 hence lightning protection is not required	
R_2 : risk of loss of service to the public	$R_2 = R_{B2} + R_{C2} + R_{M2} + R_{V2} + R_{W2} + R_{Z2}$	$5.35409e^{-08}$	$5.09424e^{-08}$	10^{-3}
		$R_2 < R_T$ for L2 hence lightning protection is not required	$R_2 < R_T$ for L2 hence lightning protection is not required	
R_3 : risk of loss of cultural heritage	$R_3 = R_{B3} + R_{V3}$	$4.08709e^{-10}$	$3.85855e^{-10}$	10^{-4}
		$R_3 < R_T$ for L3 hence lightning protection is not required	$R_3 < R_T$ for L3 hence lightning protection is not required	



IV. CONCLUSION

From the above case study, it can be concluded that while keeping the other parameters (Geographical Location, Width, Height, occupancy etc.) same, lightning protection is required for substations longer than 30m to counter the risk arising out of R1 i.e. risk of loss of human life. Hence as per the calculations, lightning protection system shall be installed on substations which are more than 30m in length.

Point worth noting is that the above conclusion is for the case study in question and cannot be generalized, for different conditions, separate calculations must be performed and as per the results, a decision has to be made for providing the lightning protection.

Air-termination system shall be designed by using any of the acceptable method as below.

- the protection angle method
- the rolling sphere method
- the mesh method.

Calculation shall be repeated by considering appropriate value for P_B from Table B.2 based on the air termination system, class of LPS to be installed. Selected class of LPS and method of air termination system shall be acceptable if the Risk R is less than tolerable risk R_T .

REFERENCES

- [1] IEC 62305 Part I, II, III, IV Lightning Protection system



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