Summary report of lightning protection risk assessment for Olympic stadium.

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Omega

Earthing – Lightning Protection - Height Safety

Contents

1. Introduction

Lightning flashes to, or nearby structures are hazardous to people, to the structures themselves, their contents and installations. The need for protection, the economic benefits of installing protection measures and the selection of adequate protection measures should be determined in terms of risk management.

1.1 Executive summary

Risk assessments, in accordance with BS EN 62305 and as required by the project specification, were carried out by Omega Red Group Ltd for Imtech Engineering Services Central.
This study, only considered the R1 risk category for the loss of human life as a result of damage to the structures. It does not consider the loss of services to the public (R_2 risk category) or any subsequent consequential financial losses as a result. Thus being as the most important factor to consider is the loss of human life.
The resulting overview is that a lightning protection system (catenary system) is not required, however a level 3 lightning protection to the stadium itself will be required.
There have been 2no risk assessments issued, one risk assessment showing the tolerable risk with no lightning protection applied to the structure and one risk assessment showing the structure with a level 3 lightning protection system.
The risk of the pitch taking a direct strike without protection is 1 in 31,900,000 chance, this figure has been generated from a risk assessment carried out by myself in which it has indicated without protection the figure of 3.19E-07 (31,900,000).

1.2 Project standards

1.2.1 BS 6651:1999

BS 6651:1999, where it relates to the installation of lightning protection systems to new structures and new extensions to existing structures, was withdrawn on 31st August 2008.

1.2.2 BS EN 62305:2011

BS EN 62305:2011 is the latest reference document for the protection against lightning. It replaced BS 6651:1999 from 1st September 2008. It is the British edition of the European standard to which all lightning protection systems to new structures, and new extensions to existing ones, are now designed, installed and maintained. BS EN 62305:2011 comprises four parts and these detail the fundamental requirements for lightning protection systems for the external and internal parts of a structure. The four parts are as follows:

Part 1: General principles
Part 2: Risk management
Part 3: Physical damage to structures and life hazard
Part 4: Electrical and electronic systems within buildings.

BS EN 62305-1:2011 provides the general principles to be followed in the protection against lightning of structures, including their installations and contents as well as persons.

BS EN 62305-2:2011 is applicable to risk assessment for a structure due to lightning flashes. Its purpose is to provide a procedure for the evaluation of such a risk.

BS EN 62305-3:2011 provides the requirements for protection of a structure against physical damage by means of a lightning protection system (LPS), and for protection against injury to living beings due to touch and step voltages in the vicinity of an LPS.

BS EN 62305-4:2011 provides information for the design, installation and maintenance of lightning electromagnetic impulse (LEMP) protection measures system for electrical and electronic systems within structures, able to reduce the risk of permanent failures due to LEMP.

1.3 Other reference documents & drawings

The following is a brief and not exhaustive list of reference documents relevant to this project:

- BS EN62305:2011 – Protection against Lightning
- A Guide to BS EN62305:2006, Protection against Lightning 2nd Edition, Furse.
- Protection against Lightning Protection, A guide to the practical application of BS EN62305:2006.

1.3.1 Drawing references

- LC201-STA-STA-S-DGA-1400, LC201-STA-SCN-A-DSE-0062,LC201-STA-ROF-A-DGA-1026, LC201-STA-ROF-A-DGA-1016, LC201-STA-ROF-A-DGA-3000, LC201-STA-ROF-A-DGA-7016, LC201-STA-ROF-A-DGA-7017, LC201-STA-SCN-A-DSE-0062, LC201-STA-STA-S-DGA-1400, LC201-STA-STA-S-DGA-1430, LC201-STA-STA-S-DGA-1440, LC201-STA-ROF-A-DGA-0040, LC201-STA-ROF-A-DGA-0041, LC201-STA-ROF-A-DGA-0042, LC201-STA-ROF-A-DGA-0043, LC201-STA-ROF-A-DGA-0055, LC201-STA-ROF-A-DGA-3008, LC201-STA-ROF-A-DGA-7018, LC201-STA-ROF-A-DGA-7019, LC201-STA-ROF-E-DGA-0033, LC201-STA-STA-S-DGA-1400, LC201-STA-STA-S-DGA-1422, LC201-STA-STA-S-DGA-1431, LC201-STA-STA-S-DGA-1461, LC201-STA-STA-S-DGA-1440, LC201-STA-STA-S-DGA-1430, LC201-STA-STA-S-DGA-1421, LC201-STA-STA-S-DGA-4803, LC201-STA-STA-S-DGA-1423, LC201-STA-STA-S-DGA-1442.

2. Risk management

2.1 Introduction

Undertaking a risk assessment is the basis for determining whether or not lightning protection measures are required, as described in BS EN 62305-2:2006. Protection against lightning is required if the risk *R*n (whether this be R_1, R_2 or R_3) is greater than the tolerable (acceptable) risk R_T. Conversely, if the risk *R*n is lower than R_T then protection measures are not required. The values of tolerable risk R_T considered are as those detailed (for the UK) in BS EN 62305-2:2006 Annex NK. Below is a brief description of each primary risk category.

2.1.1 R_1 - risk of loss of human life

This is self explanatory, is the most important risk and is considered in all cases.

2.1.2 R_2 - risk of loss of services to the public

This is the loss that can occur when a service provider (eg London Underground) cannot provide its service to its customers, due to lightning inflicted damage. There is also the subsequent risk of consequential financial loss to consider.

2.1.3 R_3 - risk of loss of cultural heritage

Again this is fairly self explanatory, where the loss of a historically important structure would be disastrous. This risk is not considered on this occasion.

2.1.4 R_4 - risk of loss of economic value

There is no tolerable risk value for R_4. Evaluating such a risk is a tortuous process, especially when the figures required are not readily available. This risk is not considered on this occasion.

3. Detailed summary

3.1 External Lighting Protection

External lightning protection is required on the stadium structure, and a lightning protection system is not required for the pitch, as without protection (catenary wire) the pitch is under the tolerable risk.

3.1.2 Internal Lighting Protection

Internal lightning protection system will only apply to the stadium building it does not need to be considered for the protection for the pitch.

4. Appendices

4.1 Risk assessment summary

Terminology used in BS EN 62305-2:2006 Risk Management Calculations

Case name:		is the structure to be protected
Date:		is the date the risk assessment is carried out
Primary risk totals		
R_T	tolerable risk	is the maximum value of the risk, which can be tolerated for the structure, in each risk category (R_1, R_2, R_3, R_4)
Protection system design parameters		
LPS	1, 2, 3, 4 or none	is the level (class) of lightning protection system
ISPD	value in kA	is the maximum peak current rating for lightning current SPDs
Lines		are the typical services entering the primary structure (possibly from a secondary structure) and connecting to electrical and electronic equipment within the structure
Environment		
*N*g	factor	is the flash density in strikes to ground per kilometre square per year (e.g. thunderstorm days per year)
*C*d	factor	is the location of the structure relative to its surroundings
*C*e	factor	is the service line density in the vicinity of the structure
Rho	value in Ωm	is the soil resistivity of the ground around the structure
Primary structure		is the structure to be protected, including a description of its overall shape and roof type
*L*b	value in M	is the length of the structure
*W*b	value in M	is the width of the structure
*H*e	value in M	is the height to the eaves of the roof of the structure
*H*r	value in M	is the height to the ridge of the roof of the structure
*H*b	value in M	is the height of the structure with a flat roof

Lines	are the typical services entering the primary structure (possibly from a secondary structure) and connecting to electrical and electronic equipment within the structure
Zones	are the defined lightning protection zones for the structure
Please note:	There can be many individual factors in the make-up of each of the items described above and as detailed in the risk assessment summaries below. This is a brief summary list. It is not practical to describe all of these in this report.

4.1.2 Olympic stadium

BS EN 62305-2:2006 Risk Management Calculations

Case name: Olympic stadium
Date: 24th April 2015

Primary risk totals

*R*1_T	5.1938E-06	Risk of loss of human life in the structure The tolerable risk is not exceeded, no additional protection required
*R*2_T	0.E00	Risk of loss of service to the public in the structure The tolerable risk is not exceeded, no additional protection required
*R*3_T	0.E00	Risk of loss of cultural heritage in the structure This risk has not been determined
*R*4_T	0.E00	Risk of loss of economic value in the structure This risk has not been determined

Protection system design parameters

LPS	Class III	
ISPD	25.00kA	Maximum peak current of equipotential bonding SPDs for each of 'n' lines defined.
Line 1 -		Protect Line 1 at its entrance to the structure with a standard equipotential bonding SPD (rated to ISPD above) in accordance with BS EN 62305-3
Line 2 -		Protect Line 2 at its entrance to the structure with a standard equipotential bonding SPD (rated to ISPD above) in accordance with BS EN 62305-3.

Note: protect incoming supplies with Type 1 SPDs (mains 12.5kA 10/350µs, data/telecom 2.5 kA 10/350µs), protect underground lines with Type 2 SPDs (tested with an 8/20µs waveform)

Protect all internal systems connected to Line 1 with a coordinated set of standard SPDs in accordance with BS EN 62305-4

Environment

*N*g	0.70	Lightning flash density (Flashes/km²/year)
*C*d	0.50	Location factor
*C*e	0.00	Environmental factor
Rho	500.00Ωm	Soil resistivity (Ohm metres)

Primary Structure Olympic stadium - cylindrical

Db	327.00m	Diameter of primary structure.
*H*b	25.00m	Height of primary structure.

Lines

Line 1	Power
Line 2	Telecoms

Zones Zone 1 Internal

BS EN 62305-2:2006 Risk Management Calculations

Project details

Project name:	New Project
Project title:	
Project address:	
Project ref:	
Calculation ref:	
Calculation notes:	
Project author:	
Created:	24 April 2015
Modified:	24 April 2015

Case details

Case name:	Olympic Stadium
Case title:	
Created:	10 May 2013
Modified:	10 May 2013
Case notes:	

Primary risk totals

R_{1_T}	5.1938E-06	Risk of loss of human life in the structure
		The tolerable risk is not exceeded, no additional protection required
R_{2_T}	0.E00	Risk of loss of service to the public in the structure
		This risk has not been determined
R_{3_T}	0.E00	Risk of loss of cultural heritage in the structure
		This risk has not been determined
R_{4_T}	0.E00	Risk of loss of economic value in the structure
		This risk has not been determined

Protection system design parameters

LPS	LPL III	Protect the structure with a Class LPL III Lightning Protection System in accordance with BS EN 62305-3
Imax	100.00kA	Maximum peak current
	97.00%	Probability that lightning current parameters are smaller than the maximum value defined above
Imin	10.00kA	Minimum peak current
	91.00%	Probability that lightning current parameters are greater than the minimum value defined above
	45.00m	Radius of rolling sphere
ISPD	25.00kA	Maximum peak current of equipotential bonding SPD's for each of 'n' lines defined (based upon simple current division concept) NOTE: The worst case surge that could be expected on a two-wire telephone or data line is 2.5kA (10/350 µs) per line (Category D test to BS EN 61643-21) to earth or 5 kA (10/350 µs) per pair.
Line 1		Protect Line 1 at its entrance to the structure with a standard equipotential bonding SPD (rated to ISPD above) in accordance with BS EN 62305-3 NOTE: Where SPDs are required but an LPS is not (ISPD = 0), protect overhead lines with Type 1 SPDs (mains 12.5kA 10/350µs, data/telecom 2.5kA 10/350µs), protect underground lines with overvoltage or Type 2 SPDs (tested with an 8/20 µs waveform)
Line 2		Protect Line 2 at its entrance to the structure with a standard equipotential bonding SPD (rated to ISPD above) in accordance with BS EN 62305-3 NOTE: Where SPDs are required but an LPS is not (ISPD = 0), protect overhead lines with Type 1 SPDs (mains 12.5kA 10/350µs, data/telecom 2.5kA 10/350µs), protect underground lines with overvoltage or Type 2 SPDs (tested with an 8/20 µs waveform)

Environment

N_g	0.70	Lightning flash density (Flashes/km²/year)
C_d	0.50	Location factor
C_e	0.00	Environmental factor
Rho	500.00 Ωm	Soil resistivity (Ohm metres)

Assessment of A_x - Collection areas (BS EN 62305-2 Annex A.2)

$A_{d/b}$	178,700.86 m²	Collection area of primary structure
$A_{d/a\ (2)}$	459.47 m²	Collection area of structure 2 (adjacent)
$A_{d/a\ (3)}$	4,129.56 m²	Collection area of structure 3 (adjacent)
A_m	537,156.58 m²	Collection area of surrounding ground
$A_{l\ (L1)}$	20,482.38 m²	Collection area of flashes striking line 1
$A_{l\ (L2)}$	20,146.97 m²	Collection area of flashes striking line 2
A_l	40,629.36 m²	Total collection area of flashes striking lines
$A_{i\ (L1)}$	559,016.99 m²	Collection area of flashes near line 1
$A_{i\ (L2)}$	559,016.99 m²	Collection area of flashes near line 2
A_i	1,118,033.99 m²	Total collection area of flashes near lines

Structures

Primary structure

Structure ID:	Olympic Stadium - Cylindrical	
D_b	327.00 m	Diameter of primary structure
H_b	25.00 m	Height of primary structure

Secondary structures

Structure No	Substation - Rectangular with a flat roof	
C_{da}	0.25	Location factor for structure 2 (adjacent)
L_a	5.00 m	Length of secondary structure
W_a	5.00 m	Width of secondary structure
H_a	3.00 m	Height of secondary structure
Structure No	Telephone Exchange - Rectangular with a flat roof	
C_{da}	0.25	Location factor for structure 3 (adjacent)
L_a	20.00 m	Length of secondary structure
W_a	20.00 m	Width of secondary structure
H_a	8.00 m	Height of secondary structure

Lines

Line 1	Powercable	
K_{S3} (L1)	1.00	Factor relevant to the characteristics of internal wiring for line 1
P_{SPD} (L1)	0.03	Probability of failure of internal systems or a service when SPDs are provided for equipotential bonding (in accordance with BS EN 62305-3) for line 1
P_{SPDc} (L1)	1.00	Probability of failure of internal systems or a service when coordinated SPDs are provided (in accordance with BS EN 62305-4) for line 1
C_t (L1)	1.00	Correction factor for a hv/lv transformer on line 1
C_{dc} (L1)	0.25	Location factor for line 1
U_w (L1)	1.50 kV	Rated impulse withstand voltage of a system connected to line 1
L_c (L1)	1,000.00 m	Length of line 1
H_c (L1)	0.00 m	Height of the conductors above ground for line 1
Line 2	Telecoms	
K_{S3} (L2)	1.00	Factor relevant to the characteristics of internal wiring for line 2
P_{SPD} (L2)	0.03	Probability of failure of internal systems or a service when SPDs are provided for equipotential bonding (in accordance with BS EN 62305-3) for line 2
P_{SPDc} (L2)	1.00	Probability of failure of internal systems or a service when coordinated SPDs are provided (in accordance with BS EN 62305-4) for line 2
C_t (L2)	1.00	Correction factor for a hv/lv transformer on line 2
C_{dc} (L2)	0.25	Location factor for line 2
U_w (L2)	1.50 kV	Rated impulse withstand voltage of a system connected to line 2
L_c (L2)	1,000.00 m	Length of line 2
H_c (L2)	0.00 m	Height of the conductors above ground for line 2

Zones

Factor	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10
r_p	2.0E-01									
r_f	1.0E-02									
r_a / r_u	1.0E-02									
h_{z1}	10									
h_{z4}	1									
L_{t1}	1.0E-04									
L_{f1}	4.0E-02									
L_{o1}	0.0E00									
L_{f2}	0.0E00									
L_{o2}	0.0E00									
L_{f3}	0.0E00									
L_{t4}	0.0E00									
L_{f4}	0.0E00									
L_{o4}	0.0E00									

Assessment of N_x - Annual number of dangerous events (BS EN 62305-2 Annex A)

$N_{d/b}$	0.062545	Average number of flashes to main structure
$N_{d/a\ (2)}$	0.000080	Average number of flashes to structure 2 (adjacent)
$N_{d/a\ (3)}$	0.000723	Average number of flashes to structure 3 (adjacent)
N_m	0.313464	Average number of flashes to surrounding ground
$N_{l\ (L1)}$	0.003584	Average number of flashes to line 1
$N_{l\ (L2)}$	0.003526	Average number of flashes to line 2
$N_{i\ (L1)}$	0.000000	Average number of flashes near line 1
$N_{i\ (L2)}$	0.000000	Average number of flashes near line 2

Assessment of P_x - Probability of damage for a structure (BS EN 62305-2 Annex NB)

Factor	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10
P_A	1									
P_B	0.1									
$P_{C\,(L1)}$	1									
$P_{C\,(L2)}$	1									
P_C	1									
K_{S1}	0.25									
K_{S2}	1									
$K_{S4\,(L1)}$	1									
$K_{S4\,(L2)}$	1									
$K_{MS\,(L1)}$	2.5E-01									
$K_{MS\,(L2)}$	2.5E-01									
$P_{MS\,(L1)}$	9.4E-01									
$P_{MS\,(L2)}$	9.4E-01									
$P_{M\,(L1)}$	9.4E-01									
$P_{M\,(L2)}$	9.4E-01									
P_M	9.964E-01									
$P_{LD\,(L1)}$	1.0E00									
$P_{LD\,(L2)}$	1.0E00									
$P_{LI\,(L1)}$	1.0E00									
$P_{LI\,(L2)}$	1.0E00									
$P_{U\,(L1)}$	3.0E-02									
$P_{U\,(L2)}$	3.0E-02									
$P_{V\,(L1)}$	3.0E-02									
$P_{V\,(L2)}$	3.0E-02									
$P_{W\,(L1)}$	1.0E00									
$P_{W\,(L2)}$	1.0E00									
$P_{Z\,(L1)}$	1.0E00									
$P_{Z\,(L2)}$	1.0E00									

Assessment of L_X - Amount of loss for a structure (BS EN 62305-2 Annex NC)

Loss factors relevant to R_1

Factor	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10
L_A	1.0E-06									
L_B	8.0E-04									
L_C	0.0E00									
L_M	0.0E00									
L_U	1.0E-06									
L_V	8.0E-04									
L_W	0.0E00									
L_Z	0.0E00									

Loss factors relevant to R_2

Factor	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10
L_B	0.0E00									
L_C	0.0E00									
L_M	0.0E00									
L_V	0.0E00									
L_W	0.0E00									
L_Z	0.0E00									

Loss factors relevant to R_3

Factor	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10
L_B	0.0E00									
L_V	0.0E00									

Loss factors relevant to R_4

Factor	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10
L_A	0.0E00									
L_B	0.0E00									
L_C	0.0E00									
L_M	0.0E00									
L_U	0.0E00									
L_V	0.0E00									
L_W	0.0E00									
L_Z	0.0E00									

Assessment of R_x - Risk components

Risk components relevant to R_1

Factor	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10
R_A	0.0E00									
R_B	5.0036E-06									
R_C	0.0E00									
R_M	0.0E00									
$R_{U\ (L1)}$	1.0994E-10									
$R_{U\ (L2)}$	1.2745E-10									
$R_{V\ (L1)}$	8.7956E-08									
$R_{V\ (L2)}$	1.0196E-07									
$R_{W\ (L1)}$	0.0E00									
$R_{W\ (L2)}$	0.0E00									
$R_{Z\ (L1)}$	0.0E00									
$R_{Z\ (L2)}$	0.0E00									

Risk components relevant to R_2

Factor	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10
R_B	0.0E00									
R_C	0.0E00									
R_M	0.0E00									
$R_{V\ (L1)}$	0.0E00									
$R_{V\ (L2)}$	0.0E00									
$R_{W\ (L1)}$	0.0E00									
$R_{W\ (L2)}$	0.0E00									
$R_{Z\ (L1)}$	0.0E00									
$R_{Z\ (L2)}$	0.0E00									

Risk components relevant to R_3

Factor	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10
R_B	0.0E00									
$R_{V\ (L1)}$	0.0E00									
$R_{V\ (L2)}$	0.0E00									

Risk components relevant to R_4

Factor	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10
R_A	0.0E00									
R_B	0.0E00									
R_C	0.0E00									
R_M	0.0E00									
$R_{U\ (L1)}$	0.0E00									
$R_{U\ (L2)}$	0.0E00									
$R_{V\ (L1)}$	0.0E00									
$R_{V\ (L2)}$	0.0E00									
$R_{W\ (L1)}$	0.0E00									
$R_{W\ (L2)}$	0.0E00									
$R_{Z\ (L1)}$	0.0E00									

Primary risk totals

R_{1_T}	5.1938E-06	Risk of loss of human life in the structure
R_{2_T}	0.E00	Risk of loss of service to the public in the structure
R_{3_T}	0.E00	Risk of loss of cultural heritage in the structure
R_{4_T}	0.E00	Risk of loss of economic value in the structure

Primary risk with respect to source of damage

R_{1_D}	5.0036E-06	Risk of loss of human life in the structure due to flashes to the structure (S1)
R_{2_D}	0.E00	Risk of loss of service to the public in the structure due to flashes to the structure (S1)
R_{3_D}	0.E00	Risk of loss of cultural heritage in the structure due to flashes to the structure (S1)
R_{4_D}	0.E00	Risk of loss of economic value in the structure due to flashes to the structure (S1)
R_{1_I}	1.9015E-07	Risk of loss of human life in the structure due to flashes influencing, but not striking the structure (S2, S3, S4)
R_{2_I}	0.E00	Risk of loss of service to the public in the structure due to flashes influencing, but not striking the structure (S2, S3, S4)
R_{3_I}	0.E00	Risk of loss of cultural heritage in the structure due to flashes influencing, but not striking the structure (S2, S3, S4)
R_{4_I}	0.E00	Risk of loss of economic value in the structure due to flashes influencing, but not striking the structure (S2, S3, S4)

Primary risk with respect to type of damage

R_{1_S}	2.374E-10	Risk of loss of human life in the structure due to injury to living beings (D1)
R_{2_S}	0.E00	Risk of loss of service to the public in the structure due to injury to living beings (D1)
R_{3_S}	0.E00	Risk of loss of cultural heritage in the structure due to injury to living beings (D1)
R_{4_S}	0.E00	Risk of loss of economic value in the structure due to injury to living beings (D1)
R_{1_F}	5.1935E-06	Risk of loss of human life in the structure due to physical damage (D2)
R_{2_F}	0.E00	Risk of loss of service to the public in the structure due to physical damage (D2)
R_{3_F}	5.1935E-06	Risk of loss of cultural heritage in the structure due to physical damage (D2)
R_{4_F}	0.E00	Risk of loss of economic value in the structure due to physical damage (D2)
R_{1_O}	0.E00	Risk of loss of human life in the structure due to failure of internal systems (D3)
R_{2_O}	0.E00	Risk of loss of service to the public in the structure due to failure of internal systems (D3)
R_{3_O}	0.E00	Risk of loss of cultural heritage in the structure due to failure of internal systems (D3)
R_{4_O}	0.E00	Risk of loss of economic value in the structure due to failure of internal systems (D3)

BS EN 62305-2:2006 Risk Management Calculations

Project details

Project name:	New Project
Project title:	
Project address:	
Project ref:	
Calculation ref:	
Calculation notes:	
Project author:	
Created:	24 April 2015
Modified:	24 April 2015

Case details

Case name:	Olympic Stadium
Case title:	
Created:	10 May 2013
Modified:	10 May 2013
Case notes:	

Primary risk totals

R_{1_T}	5.6375E-05	Risk of loss of human life in the structure The tolerable risk is exceeded, therfore protection measures must be instigated
R_{2_T}	0.E00	Risk of loss of service to the public in the structure This risk has not been determined
R_{3_T}	0.E00	Risk of loss of cultural heritage in the structure This risk has not been determined
R_{4_T}	0.E00	Risk of loss of economic value in the structure This risk has not been determined

Protection system design parameters

LPS	None	
ISPD	0.00kA	Maximum peak current of equipotential bonding SPD's for each of 'n' lines defined (based upon simple current division concept) NOTE: The worst case surge that could be expected on a two-wire telephone or data line is 2.5kA (10/350 µs) per line (Category D test to BS EN 61643-21) to earth or 5 kA (10/350 µs) per pair.

Environment

N_g	0.70	Lightning flash density (Flashes/km²/year)
C_d	0.50	Location factor
C_e	0.00	Environmental factor
Rho	500.00 Ωm	Soil resistivity (Ohm metres)

Assessment of A_x - Collection areas (BS EN 62305-2 Annex A.2)

$A_{d/b}$	178,700.86 m²	Collection area of primary structure
$A_{d/a\ (2)}$	459.47 m²	Collection area of structure 2 (adjacent)
$A_{d/a\ (3)}$	4,129.56 m²	Collection area of structure 3 (adjacent)
A_m	537,156.58 m²	Collection area of surrounding ground
$A_{l\ (L1)}$	20,482.38 m²	Collection area of flashes striking line 1
$A_{l\ (L2)}$	20,146.97 m²	Collection area of flashes striking line 2
A_l	40,629.36 m²	Total collection area of flashes striking lines
$A_{i\ (L1)}$	559,016.99 m²	Collection area of flashes near line 1
$A_{i\ (L2)}$	559,016.99 m²	Collection area of flashes near line 2
A_i	1,118,033.99 m²	Total collection area of flashes near lines

Structures

Primary structure

Structure ID:	Olympic Stadium - Cylindrical	
D_b	327.00 m	Diameter of primary structure
H_b	25.00 m	Height of primary structure

Secondary structures

Structure No	Substation - Rectangular with a flat roof	
C_{da}	0.25	Location factor for structure 2 (adjacent)
L_a	5.00 m	Length of secondary structure
W_a	5.00 m	Width of secondary structure
H_a	3.00 m	Height of secondary structure
Structure No	Telephone Exchange - Rectangular with a flat roof	
C_{da}	0.25	Location factor for structure 3 (adjacent)
L_a	20.00 m	Length of secondary structure
W_a	20.00 m	Width of secondary structure
H_a	8.00 m	Height of secondary structure

Lines

Line 1	Powercable	
$K_{S3\ (L1)}$	1.00	Factor relevant to the characteristics of internal wiring for line 1
$P_{SPD\ (L1)}$	1.00	Probability of failure of internal systems or a service when SPDs are provided for equipotential bonding (in accordance with BS EN 62305-3) for line 1
$P_{SPDc\ (L1)}$	1.00	Probability of failure of internal systems or a service when coordinated SPDs are provided (in accordance with BS EN 62305-4) for line 1
$C_{t\ (L1)}$	1.00	Correction factor for a hv/lv transformer on line 1
$C_{dc\ (L1)}$	0.25	Location factor for line 1
$U_{w\ (L1)}$	1.50 kV	Rated impulse withstand voltage of a system connected to line 1
$L_{c\ (L1)}$	1,000.00 m	Length of line 1
$H_{c\ (L1)}$	0.00 m	Height of the conductors above ground for line 1
Line 2	Telecoms	
$K_{S3\ (L2)}$	1.00	Factor relevant to the characteristics of internal wiring for line 2
$P_{SPD\ (L2)}$	1.00	Probability of failure of internal systems or a service when SPDs are provided for equipotential bonding (in accordance with BS EN 62305-3) for line 2
$P_{SPDc\ (L2)}$	1.00	Probability of failure of internal systems or a service when coordinated SPDs are provided (in accordance with BS EN 62305-4) for line 2
$C_{t\ (L2)}$	1.00	Correction factor for a hv/lv transformer on line 2
$C_{dc\ (L2)}$	0.25	Location factor for line 2
$U_{w\ (L2)}$	1.50 kV	Rated impulse withstand voltage of a system connected to line 2
$L_{c\ (L2)}$	1,000.00 m	Length of line 2
$H_{c\ (L2)}$	0.00 m	Height of the conductors above ground for line 2

Zones

Factor	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10
r_p	2.0E-01									
r_f	1.0E-02									
r_a / r_u	1.0E-02									
h_{z1}	10									
h_{z4}	1									
L_{t1}	1.0E-04									
L_{f1}	4.0E-02									
L_{o1}	0.0E00									
L_{f2}	0.0E00									
L_{o2}	0.0E00									
L_{f3}	0.0E00									
L_{t4}	0.0E00									
L_{f4}	0.0E00									
L_{o4}	0.0E00									

Assessment of N_x - Annual number of dangerous events (BS EN 62305-2 Annex A)

$N_{d/b}$	0.062545	Average number of flashes to main structure
$N_{d/a\ (2)}$	0.000080	Average number of flashes to structure 2 (adjacent)
$N_{d/a\ (3)}$	0.000723	Average number of flashes to structure 3 (adjacent)
N_m	0.313464	Average number of flashes to surrounding ground
$N_{l\ (L1)}$	0.003584	Average number of flashes to line 1
$N_{l\ (L2)}$	0.003526	Average number of flashes to line 2
$N_{i\ (L1)}$	0.000000	Average number of flashes near line 1
$N_{i\ (L2)}$	0.000000	Average number of flashes near line 2

Assessment of P_x - Probability of damage for a structure (BS EN 62305-2 Annex NB)

Factor	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10
P_A	1									
P_B	1									
$P_{C\,(L1)}$	1									
$P_{C\,(L2)}$	1									
P_C	1									
K_{S1}	0.25									
K_{S2}	1									
$K_{S4\,(L1)}$	1									
$K_{S4\,(L2)}$	1									
$K_{MS\,(L1)}$	2.5E-01									
$K_{MS\,(L2)}$	2.5E-01									
$P_{MS\,(L1)}$	9.4E-01									
$P_{MS\,(L2)}$	9.4E-01									
$P_{M\,(L1)}$	9.4E-01									
$P_{M\,(L2)}$	9.4E-01									
P_M	9.964E-01									
$P_{LD\,(L1)}$	1.0E00									
$P_{LD\,(L2)}$	1.0E00									
$P_{LI\,(L1)}$	1.0E00									
$P_{LI\,(L2)}$	1.0E00									
$P_{U\,(L1)}$	1.0E00									
$P_{U\,(L2)}$	1.0E00									
$P_{V\,(L1)}$	1.0E00									
$P_{V\,(L2)}$	1.0E00									
$P_{W\,(L1)}$	1.0E00									
$P_{W\,(L2)}$	1.0E00									
$P_{Z\,(L1)}$	1.0E00									
$P_{Z\,(L2)}$	1.0E00									

Assessment of L_x - Amount of loss for a structure (BS EN 62305-2 Annex NC)

Loss factors relevant to R_1

Factor	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10
L_A	1.0E-06									
L_B	8.0E-04									
L_C	0.0E00									
L_M	0.0E00									
L_U	1.0E-06									
L_V	8.0E-04									
L_W	0.0E00									
L_Z	0.0E00									

Loss factors relevant to R_2

Factor	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10
L_B	0.0E00									
L_C	0.0E00									
L_M	0.0E00									
L_V	0.0E00									
L_W	0.0E00									
L_Z	0.0E00									

Loss factors relevant to R_3

Factor	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10
L_B	0.0E00									
L_V	0.0E00									

Loss factors relevant to R_4

Factor	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10
L_A	0.0E00									
L_B	0.0E00									
L_C	0.0E00									
L_M	0.0E00									
L_U	0.0E00									
L_V	0.0E00									
L_W	0.0E00									
L_Z	0.0E00									

Assessment of R_x - Risk components

Risk components relevant to R_1

Factor	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10
R_A	0.0E00									
R_B	5.0036E-05									
R_C	0.0E00									
R_M	0.0E00									
$R_{U\ (L1)}$	3.6648E-09									
$R_{U\ (L2)}$	4.2484E-09									
$R_{V\ (L1)}$	2.9319E-06									
$R_{V\ (L2)}$	3.3987E-06									
$R_{W\ (L1)}$	0.0E00									
$R_{W\ (L2)}$	0.0E00									
$R_{Z\ (L1)}$	0.0E00									
$R_{Z\ (L2)}$	0.0E00									

Risk components relevant to R_2

Factor	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10
R_B	0.0E00									
R_C	0.0E00									
R_M	0.0E00									
$R_{V\ (L1)}$	0.0E00									
$R_{V\ (L2)}$	0.0E00									
$R_{W\ (L1)}$	0.0E00									
$R_{W\ (L2)}$	0.0E00									
$R_{Z\ (L1)}$	0.0E00									
$R_{Z\ (L2)}$	0.0E00									

Risk components relevant to R_3

Factor	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10
R_B	0.0E00									
$R_{V\ (L1)}$	0.0E00									
$R_{V\ (L2)}$	0.0E00									

Risk components relevant to R_4

Factor	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10
R_A	0.0E00									
R_B	0.0E00									
R_C	0.0E00									
R_M	0.0E00									
$R_{U\ (L1)}$	0.0E00									
$R_{U\ (L2)}$	0.0E00									
$R_{V\ (L1)}$	0.0E00									
$R_{V\ (L2)}$	0.0E00									
$R_{W\ (L1)}$	0.0E00									
$R_{W\ (L2)}$	0.0E00									
$R_{Z\ (L1)}$	0.0E00									
$R_{Z\ (L2)}$	0.0E00									

Primary risk totals

R_{1_T}	5.6375E-05	Risk of loss of human life in the structure
R_{2_T}	0.E00	Risk of loss of service to the public in the structure
R_{3_T}	0.E00	Risk of loss of cultural heritage in the structure
R_{4_T}	0.E00	Risk of loss of economic value in the structure

Primary risk with respect to source of damage

R_{1_D}	5.0036E-05	Risk of loss of human life in the structure due to flashes to the structure (S1)
R_{2_D}	0.E00	Risk of loss of service to the public in the structure due to flashes to the structure (S1)
R_{3_D}	0.E00	Risk of loss of cultural heritage in the structure due to flashes to the structure (S1)
R_{4_D}	0.E00	Risk of loss of economic value in the structure due to flashes to the structure (S1)
R_{1_I}	6.3385E-06	Risk of loss of human life in the structure due to flashes influencing, but not striking the structure (S2, S3, S4)
R_{2_I}	0.E00	Risk of loss of service to the public in the structure due to flashes influencing, but not striking the structure (S2, S3, S4)
R_{3_I}	0.E00	Risk of loss of cultural heritage in the structure due to flashes influencing, but not striking the structure (S2, S3, S4)
R_{4_I}	0.E00	Risk of loss of economic value in the structure due to flashes influencing, but not striking the structure (S2, S3, S4)

Primary risk with respect to type of damage

R_{1_S}	7.9132E-09	Risk of loss of human life in the structure due to injury to living beings (D1)
R_{2_S}	0.E00	Risk of loss of service to the public in the structure due to injury to living beings (D1)
R_{3_S}	0.E00	Risk of loss of cultural heritage in the structure due to injury to living beings (D1)
R_{4_S}	0.E00	Risk of loss of economic value in the structure due to injury to living beings (D1)
R_{1_F}	5.6367E-05	Risk of loss of human life in the structure due to physical damage (D2)
R_{2_F}	0.E00	Risk of loss of service to the public in the structure due to physical damage (D2)
R_{3_F}	5.6367E-05	Risk of loss of cultural heritage in the structure due to physical damage (D2)
R_{4_F}	0.E00	Risk of loss of economic value in the structure due to physical damage (D2)
R_{1_O}	0.E00	Risk of loss of human life in the structure due to failure of internal systems (D3)
R_{2_O}	0.E00	Risk of loss of service to the public in the structure due to failure of internal systems (D3)
R_{3_O}	0.E00	Risk of loss of cultural heritage in the structure due to failure of internal systems (D3)
R_{4_O}	0.E00	Risk of loss of economic value in the structure due to failure of internal systems (D3)