Date: 26.11.2025 **Project No.: 11/032**

Lightning protection
Risk management

Created according to international standard:
IEC 62305-2:2010-12

Considering the country-specific annexes for:
EN 62305-2:2012-03

Summary of measures for
reducing damage caused by lightning effects,
resulting from the risk management
concerning the following project:

Project / object description:

Grasmo solkraftverk
Grasmo
2223 Eidskog
Norge

Customer / principal:

Company
DEHN Norge AS

Rådhusgata 11
3211 Sandefjord
Norge

Risk assessment by:

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Contents

1. Abbreviations

a	Amortisation rate
a_t	Amortisation period
c_a	Value of animals in a zone in currency
c_b	Value of a zone of the structure in currency
c_c	Value of the contents of a zone in currency
c_s	Value of the systems in a zone (including their activities) in currency
c_t	Total value of the structure in currency
C_D;C_{DJ}	Location factor
C_L	Annual costs of the total loss without protection measures
C_{PM}	Annual costs of the selected protection measures
C_{RL}	Annual costs of the residual loss
EB	Lightning equipotential bonding
H	Height of the structure
H_P	Highest point of the structure
i	Interest rate
K_{S1}	Factor relevant to the shielding effectiveness of a structure (external spatial shielding)
K_{S1W}	Mesh size of the shielding of a structure
K_{S2}	Factor relevant to the shielding effectiveness of a structure (external spatial shielding)
K_{S2W}	Mesh size of the shielding within a structure
L1	Loss of human life
L2	Loss of service to the public
L3	Loss of cultural heritage
L4	Loss of economic value
L	Length of the structure
LEMP	Lightning electromagnetic impulse
LP	Lightning protection (consisting of a lightning protection system (LPS) and LEMP protection measures)
LPL	Lightning protection level
LPS	Lightning protection system
LPZ	Lightning protection zone (zone where the lightning electromagnetic environment is defined)
m	Maintenance rates
N_D	Frequency of dangerous events caused by lightning strikes to a structure
N_G	Ground flash density
P_B	Probability that a lightning strike to a structure causes physical damage
P_{EB}	Lightning equipotential bonding
P_{SPD}	Coordinated SPD system
R	Risk
R_1	Risk of loss of human life in a structure
R_2	Risk of loss of service to the public
R_3	Risk of loss of cultural heritage
R_4	Risk of loss of economical value in a structure
R_A	Risk component (injury to living beings - Lightning strike to the structure)
R_B	Risk component (physical damage to a structure - Lightning strike to the structure)

R_C	Risk component (failure of internal systems - Lightning strike to the structure)
R_M	Risk component (failure of internal systems - Lightning strike near the structure)
R_U	Risk component (injury to living beings - Lightning strike to a connected supply line)
R_V	Risk component (physical damage to a structure - Lightning strike to a connected supply line)
R_W	Risk component (failure of internal systems - Lightning strike to a connected supply line)
R_Z	Risk component (failure of internal systems - Lightning strike near the connected supply line)
R_T	Tolerable risk (maximum value of the risk which can be tolerated for the structure to be protected)
r_f	Reduction factor considering the fire risk in a structure
r_p	Reduction factor considering the measures to reduce the consequences of a fire
S_M	Annual savings
SPD	Surge protection device
SPM	LEMP protection measures (measures to reduce the risk of failure of electrical and electronic equipment due to LEMP)
t_{ex}	Duration of the presence of a dangerous explosive atmosphere
W	Width of the structure
Z	Zones of a structure

2. Normative basics

The EN 62305 standard series consists of the following parts:

- EN 62305-1:2011-02 - "Protection against lightning - Part 1: General principles“

- EN 62305-2:2012-03 - "Protection against lightning - Part 2: Risk management"

- EN 62305-3:2011-02 - "Protection against lightning - Part 3: Physical damage to structures and life hazard“

- EN 62305-4:2011-02 - "Protection against lightning - Part 4: Electrical and electronic systems within structures“

3. Risk and sources of damage

In order to avoid damage resulting from a lightning strike, specific protection measures must be taken for the objects to be protected. The risk management described in the EN 62305-2:2012-03 standard includes a risk analysis which allows to determine the lightning protection requirements of a structure. The aim of the risk management is to reduce the risk to an acceptable level by taking protection measures.

To determine the prevailing risk, the relevant object must be connsidered without any protection measures (actual condition). Risks that may be caused as a result of direct / indirect lightning strikes to the structure and supply lines are referred to as risk R. The risk defines the possible annual loss. Risks that must be assessed for a structure could be:

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

All risks or the individual risks must be assessed depending on the type of consideration. Every risk is defined with a tolerable risk in form of a numerical value. To achieve a tolerable risk, technically and economically sound protection measures are defined e.g. external lightning protection measures according to EN 62305-3:2011-02 and SPD measures according to EN 62305-4:2011-02.

To be able to determine the risk focus more exactly, the risks are considered in detail. Every risk consists of a sum of risk components.

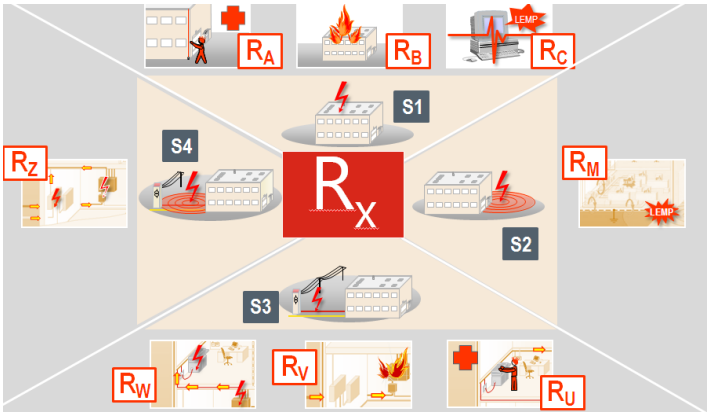
- $R_1 = R_A + R_B + R_C + R_M + R_U + R_V + R_W + R_Z$
- $R_2 = R_B + R_C + R_M + R_V + R_W + R_Z$
- $R_3 = R_B + R_V$
- $R_4 = R_A + R_B + R_C + R_M + R_U + R_V + R_W + R_Z$

Every risk component describes a certain danger and thus a possible loss. The loss resulting from lightning effects is defined as follows:

- L1 = Loss of human life
- L2 = Loss of service to the public
- L3 = Loss of cultural heritage
- L4 = Loss of economic value

The possible loss is assigned to the risk components as follows:

The risk components are differentiated according to the sources of damage.



Source of damage S1: Risk components based on lightning strikes to the structure

R_A Component which refers to injury of living beings caused by an electric shock resulting from touch and step voltage within the structure and up to 3 m around the down conductors outside the structure. Type of damage L1 may occur for agricultural buildings and type of damage L4 with possible loss of animals.

R_B Component which refers to physical damage caused by dangerous sparking within the structure resulting in fire and explosion. Even the environment can be at risk. All types of damage can occur (L1, L2, L3, L4).

R_C Component which refers to the failure of internal systems caused by LEMP. Types of

damage L2 and L4 can occur in all cases and type of damage L1 in case of structures with a risk of explosion and hospitals or other structures in which the failure of internal systems can be lead to loss of human life.

Source of damage S2: Risk components for a structure as a result of lightning strikes near the structure

R_M Component which refers to the failure of internal systems caused by LEMP. Types of damage L2 and L4 can occur in all cases and type of damage L1 in case of structures with a risk of explosion and hospitals or other structures in which the failure of internal systems can be lead to loss of human life.

Source of damage S3: Risk components for a structure as a result of lighting strikes to the incoming supply line

R_U Component which refers to injury of living beings caused by an electric shock resulting from touch voltage within the structure. Type of damage L1 may occur for agriculture facilities and type of damage L4 with possible loss of animals.

R_V Component which refers to physical damage caused by the lightning current injected into the structure by means of or along the supply line (fire or explosion due to dangerous sparking between the external installation and the metal parts, typically at the point where the supply line enters the structure). All types of damage (L1, L2, L3, L4) can occur.

R_W Component which refers to the failure of internal systems caused by overvoltages injected into the structure by means of incoming supply lines. Types of damage L2 and L4 can occur in all cases and type of damage L1 in case of structures with a risk of explosion and hospitals or other structures in which the failure of internal systems can be lead to loss of human life.

Source of damage S4: Risk components for a structure as a result of lighting strikes near the incoming supply line

R_Z Component which refers to the failure of internal systems caused by overvoltages injected into the structure by means of incoming supply lines. Types of damage L2 and L4 can occur in all cases and type of damage L1 in case of structures with a risk of explosion and hospitals or other structures in which the failure of internal systems can be lead to loss of human life.

The risk components allow to analyse the risks and measures to avoid possible loss can be taken.

The following risk analysis according to EN 62305-2:2012-03 for the project Grasmo solkraftverk - object Grasmo Solkraftverk shows the necessity of protection measures. The risk potential for the structure is determined and, if necessary, measures to reduce the risk have to be taken. The result of the risk analysis not only specifies the class of LPS, but also provides a complete protection concept including the necessary LEMP protection measures.

As a result, an economically reasonable selection of protection measures suitable for the properties and use of the structure is ensured.

4. Project data

4.1 Selection of risks to be considered

Due to the type and use of the structure, object Grasmo Solkraftverk, the following risks were selected and considered:

Risk R_2:	Risk of loss of service to the public;	R_T: 1,00E-03

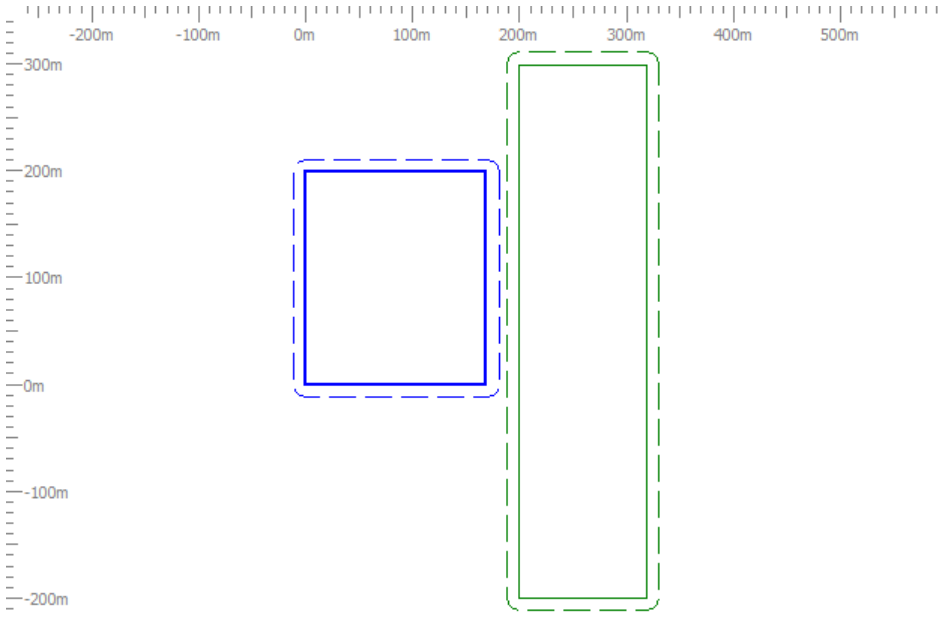
The tolerable risks R_T were defined by selecting the risks.

The aim of a risk analysis is to reduce the risk to a acceptable level RT by an economically sound selection of protection measures.

4.2 Geographic and building parameters

The ground flash density Ng is the basis for a risk analysis according to EN 62305-2:2012-03. It defines the number of direct lightning strikes in 1 / year / km². A value of 0,80 lightning strikes / year / km² was determined for the location of the object Grasmo Solkraftverk by means of the ground flash density map. As a result, there is a calculated number of 8,00 of thunderstorm days per year for the location of the project.

The dimensions of the building are decisive for the risk of a direct strike. The collection areas for direct / indirect lightning strikes are determined based on it's dimensions.
This results in a calculated collection area for direct lightning strikes of 119 374,00 m² and for indirect lightning strikes (near the structure) of 1 637 044,00 m².



The environment surrounding the structure is an important factor for determining the number of direct /

indirect lightning strikes. It was defined as follows for the building Grasmo Solkraftverk:
Relative location C_{db}: 1,00

If the ground flash density is referred to the size and the environment of the structure, a frequency of direct strikes Nd to the structure of 0,0955 strikes / year and indirect strikes near the structure of 1,3096 strikes / year is to be expected.

4.3 Division of the structure into lightning protection zones/zones

The structure Grasmo Solkraftverk was not divided into lightning protection zones / zones.

5. Supply lines

All incoming and outgoing supply lines of the structure to be considered must be taken into account in the risk analysis. Conductive pipes do not have to be considered if they are connected to the main earthing busbar of the structure. If this is not the case, the risk of incoming pipes should be considered in the risk analysis (observe that equipotential bonding is required!).

The following supply lines were considered for the structure Grasmo Solkraftverk in the risk analysis:

- 230/400V
- Kommunikasjon

5.1 230/400V

Installation factor:	Buried
Type of conductor:	Power supply line
Environment:	Rural
Connection of the conductor:	No special conditions
Transformer:	LV power supply, telecommunication or data line
Conductor shielding:	External: Aerial or unshielded buried cable

The conductor length outside the structure up to the next node is 200,00 m.

Based on this, the following collection areas were determined for the supply line:
- Collection area for direct lightning strikes to a supply line: 8 000,00 m²
- Collection area for indirect lightning strikes near a supply line: 800 000,00 m²

The dielectric strength of the electrical equipment which is connected with the 230/400V is Uw <= 1.0 kV

The conductors in the building are installed via Unshielded cable – no routing precaution in order to avoid loops.

5.2 Kommunikasjon

Installation factor:	Buried
Type of conductor:	Power supply line
Environment:	Rural
Connection of the conductor:	No special conditions
Transformer:	LV power supply, telecommunication or data line
Conductor shielding:	External: Aerial or unshielded buried cable

The conductor length outside the structure up to the next node is 1 000,00 m.

Based on this, the following collection areas were determined for the supply line:
- Collection area for direct lightning strikes to a supply line: 40 000,00 m²
- Collection area for indirect lightning strikes near a supply line: 4 000 000,00 m²

The dielectric strength of the electrical equipment which is connected with the Kommunikasjon is Uw <= 1.0 kV

The conductors in the building are installed via Unshielded cable – no routing precaution in order to avoid loops.

6. Properties of the structure

6.1 Risk of fire

The risk of fire is one of the most important criteria for determining whether an LPS (lightning protection system) must be installed. The risk of fire is classified according to the specific fire load. The fire load should be determined by a fire safety expert or defined after consultation with the proprietor of the building and his / her insurance company. A distinction is made according to the following criteria:

- None
- Low (specific fire load in the building less than 400 MJ/m²)
- Ordinary (specific fire load in the building between 400 MJ/m² and 800 MJ/m²)
- High (specific fire load in the building greater than 800 MJ/m²)
- Explosion: zone 2 / 22
- Explosion: zone 1 / 21
- Explosion: zone 0 / 20

The risk of fire in a structure is an important factor for determining the required protection measures. The risk of fire for the structure Grasmo Solkraftverk was defined as follows:

- Low risk of fire

6.2 Measures to reduce the consequences of a fire

The following measures were selected to reduce the consequences of a fire:

- No measures

6.3 External spatial shielding

Spatial shielding attenuates the magnetic field within a structure caused by lightning strikes to or near the object and reduces internal surges.
This can be achieved by an intermeshed equipotential bonding network in which all conductive parts of the structure and the internal systems are integrated. Consequently, the external / internal spatial shield is only a part of a shielded building structure. It must be observed that metal coverings and claddings are connected to one another and conductively to the equipotential bonding of the building. In this context, the relevant normative requirements must be observed.

Covering of the structure Grasmo Solkraftverk:

- No shielding

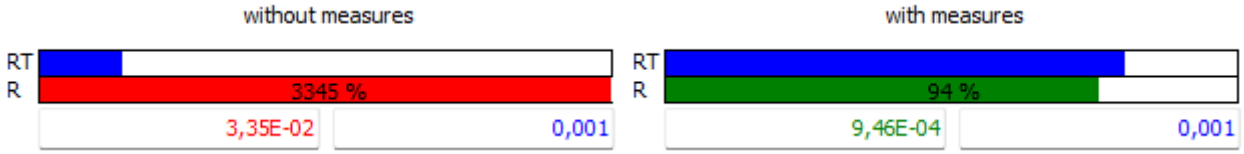
7. Risk assessment

As described in 4.1, the following risks according to 7.were assessed. The blue bar shows the tolerable risk value and the green / red bar shows the risk determined.

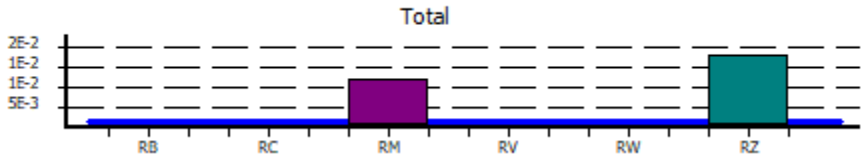
7.1 Risk R2, Service to the public

The risk R2, failure of services to the public, was determined for the structure Grasmo Solkraftverk as follows:

Tolerable risk R_T:	1,00E-03
Calculated risk R2 (unprotected):	3,35E-02
Calculated risk R2 (protected):	9,46E-04



The risk R2 consists of following risk components:



To reduce the risk, it is necessary to take measures as described in 7.

7.2 Selection of protection measures

The risk was reduced to an acceptable level by selecting the following protection measures.

This selection of protection measures is part of the risk management for the object Grasmo Solkraftverk and is only valid in connection with this object.

Measures With protection/target state:

Area		Measures	Factor
	pB:	Lightning protection system (LPS) Class of LPS IV	2.000E-01
	pEB:	Lightning equipotential bonding Equipotential bonding for LPL III or IV	5.000E-02
		230/400V:	
	pSPD:	Coordinated SPD protection LPL II	2.000E-02
		Kommunikasjon:	
	pSPD:	Coordinated SPD protection LPL II	2.000E-02

8. Legal obligation

The risk analysis performed refers to the information provided by the operator and/or proprietor of the building or expert which has been assumed, assessed or defined on site. Please note that this information must be verified after assessment.

The procedure of the DEHNsupport software for calculating the risks is based on the EN 62305-2:2012-03 standard.

Please note that all assumptions, documents, illustrations, drawings, dimensions, parameters and results are not legally binding for the person performing the risk analysis.

_____	_____
Place, date	Stamp, signature

9. General information

9.1 Components of the external lightning protection system

Lightning protection components used for the construction of the external lightning protection system must comply with the mechanical and electrical requirements defined in the EN 62561-x standard series. This standard series is for example divided into following parts:

- EN 62561-1:2012	Requirements for connection components
- EN 62561-2:2012	Requirements for conductors and earth electrodes
- EN 62561-3:2012	Requirements for isolating spark gaps
- EN 62561-4:2011	Requirements for conductor fasteners
- EN 62561-5:2011	Requirements for electrode inspection housings and earth electrode seals

9.1.1 EN 62561-1:2012 Requirements for connection components

The requirements for connection components such as clamps are defined in EN 62561-1. For the installer of lightning protection systems this means that the connection components are to be selected for the load (H or N) to be expected at the place of installation. Therefore, a clamp for load H (100 kA) is to be used e.g. for an air-termination rod (100% lightning current) and a clamp for load N (50 kA) e.g. for a mesh or an earth entry (lightning current already distributed). The suitability for these applications must be proven by the manufacturer.

9.1.2 EN 62561-2:2012 Requirements for conductors and earth electrodes

The EN 62561-2 specifies concrete requirements for conductors, such as air-termination and down conductors as well as earth electrodes. These are defined as follows:

- Mechanical properties (minimum tensile strength and elongation),
- Electrical properties (maximum resistivity) and
- Corrosion protection properties (artificial aging).

The EN 62561-2 standard also specifies the requirements for earth electrodes and earth rods. In this context, the material, geometry, minimum dimensions as well as the mechanical and electrical properties are important. These normative requirements are relevant product features, which must be documented in the manufacturers' documents and product datasheets.

9.1.3 EN 62561-3:2012 Requirements for isolating spark gaps

Isolating spark gaps can be used to galvanically isolate an earth-termination system.EN 62561-3 specifies that isolating spark gaps must be dimensioned in such a way that the components, if installed according to the manufacturer's instructions, are reliable, durable and safe for persons and nearby installations.

9.1.4 EN 62561-4:2011 Requirements for conductor fasteners

The EN 62561-4 standard specifies the requirements and tests for metal and non-metal conductor fasteners used with air-termination and down conductors.

9.1.5 EN 62561-5:2011 Requirements for electrode inspection housings and earth electrode seals

All earth electrode inspection housings and earth electrode seals must be designed in such a way that they are reliable and safe for persons and the environment when used as intended. EN 62561-5 specifies the requirements and tests for earth electrode inspection housings (e.g. pressure load) and for earth electrode seals (e.g. leak test).

10. Definition

Coordinated SPD system

SPDs properly selected, coordinated and installed to form a system intended to reduce failures of electrical

and electronic systems.

Isolating interfaces
Devices which are capable of reducing conducted surges on lines entering the LPZ. These include isolation transformers with earthed screen between windings, metal-free fibre optic cables and opto-isolators. Insulation withstand characteristics of these devices are suitable for this application intrinsically or via SPD.

LEMP (lightning electromagnetic impulse)
All electromagnetic effects of lightning current via resistive, inductive and capacitive coupling, which create surges and electromagnetic fields.

LP (lightning protection)
Complete system for protection of structures against lightning, including their internal systems and contents, as well as persons, in general consisting of an LPS and SPM.

LPL (lightning protection level)
Number related to a set of lightning current parameters values relevant to the probability that the associated maximum and minimum design values will not be exceeded in naturally occurring lightning.

LPS (lightning protection system)
Complete system used to reduce physical damage due to lightning flashes to a structure.

EB (lightning equipotential bonding)
Bonding to LPS of separated metallic parts, by direct conductive connections or via surge protective devices, to reduce potential differences caused by lightning current.

SPD (surge protection device)
Device intended to limit transient overvoltages and divert surge currents; contains at least one non-linear component.

Node
Point on a line from which onward surge propagation can be assumed to be neglected. Examples of nodes are a point on a power line branch distribution at an HV / LV transformer or on a power substation, a telecommunication exchange or an equipment (e.g. multiplexer or xDSL equipment) on a telecommunication line.

Physical damage
Damage to a structure (or to its contents) due to mechanical, thermal, chemical or explosive effects of lightning.

Injury to living beings
Permanent injuries, including loss of life, to people or to animals by electric shock due to touch and step voltages caused by lightning.

Risk R
Value of probable average annual loss (humans and goods) due to lightning, relative to the total value (humans and goods) of the structure to be protected.

Zone of a structure ZS
Part of a structure with homogeneous characteristics where only one set of parameters is involved in assessment of a risk component.

LPZ (lightning protection zone)
Zone where the lightning electromagnetic environment is defined. The zone boundaries of an LPZ are not necessarily physical boundaries (e.g. walls, floor and ceiling).

Magnetic shield
Closed, metallic, grid-like or continuous screen enveloping the structure to be protected, or part of it, used to reduce failures of electrical and electronic systems.

Lightning protective cable
Special cable with increased dielectric strength and whose metallic sheath is in continuous contact with the soil either directly or by use of conducting plastic covering.

Lightning protective cable duct
Cable duct of low resistivity in contact with the soil (concrete with interconnected structural steel reinforcements or metallic duct).