Tool for Lightning Protection Design and Risk Assessment per EN IEC 62305:2024

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***Abstract*—This paper presents the Lightning Protection Tool, a web-based engineering application that implements the complete calculation framework of EN IEC 62305:2024 Parts 1-4 for lightning protection system design and risk assessment. The tool covers risk management (Part 2), external lightning protection system design (Part 3), and internal surge protection measures (Part 4) within a single browser-based interface. To verify the correctness of the implementation, the tool is benchmarked against the three official case studies presented in Annex F of EN IEC 62305-2:2024: a residential house, an office building, and a hospital. Computed values for collection areas, annual numbers of dangerous events, and all relevant risk components are compared with the standard's tabulated reference results. The tool produces values nearly identical to the reference results, validating LPT as a conforming computational aid for lightning protection practitioners and engineering educators.**

***Keywords*—Lightning protection system, risk assessment, EN IEC 62305, building protection**

I. INTRODUCTION

Lightning is a significant natural hazard responsible for substantial loss of human life and economic damage each year. The primary international framework for the design and assessment of lightning protection systems (LPS) is the EN IEC 62305 series of standards [1]–[4], which provides a structured probabilistic risk management methodology. The 2024 revision of the series introduced updated tables, a clearer treatment of the lightning ground strike-point density N_{SG} as the primary site-assessment parameter, an explicit thunderstorm warning system (TWS) factor, and a more prominent frequency-of-damage assessment alongside the established risk criterion.

Lightning phenomena and their interaction with structures have been extensively studied, with comprehensive treatments available in the literature [5], [6].

In practice, a complete EN IEC 62305-2 risk assessment for even a moderately complex building with several service lines and multiple risk zones requires the evaluation of up to 16 risk components across every zone, together with dozens of intermediate probability and loss factors. Performing this by hand is error-prone and time-consuming; yet, at the time of writing, freely available or openly documented tools implementing the 2024 edition of the standard remain scarce.

Several commercial packages address lightning risk assessment, such as LPSD [7] and similar proprietary platforms, but these are generally desktop applications with limited accessibility. Open or web-based tools that fully implement the 2024 edition and cover all four parts of the standard have not been widely reported in the literature. LPT is intended as a freely accessible alternative to commercial desktop packages, lowering the barrier of entry for smaller engineering practices, independent designers, and engineering educators who require a conforming calculation environment without licensing costs.

This paper describes LPT (Lightning Protection Tool), an open-architecture web application developed to fill this gap. LPT covers the full scope of EN IEC 62305:2024 Parts 2-4 in three interconnected modules and produces PDF assessment reports suitable for submission. The paper's central contribution is a systematic benchmark of LPT against the three normative case studies in Annex F of EN IEC 62305-2:2024, which constitutes the standard's own reference for verifying correct calculation.

The methodology adopted in this work follows the IEC 62305 framework, which has been widely analyzed and discussed in the literature, particularly with respect to lightning density parameters and risk assessment procedures [8], [9].

The remainder of the paper is organised as follows. Section II describes the tool architecture and scope. Section III outlines the benchmark methodology. Section IV presents the comparison results for each case study. Section V discusses the findings, and Section VI concludes the paper.

II. TOOL ARCHITECTURE

LPT is implemented as a Python web application. The back end uses the FastAPI framework [10] with Uvicorn as the ASGI server. The front end is a single-page application served as a static HTML/JavaScript file. The high-level architecture is shown in Fig. 1. Projects are serialised to JSON and can be stored locally or exported for archival. A built-in report generator produces structured PDF assessment documents. The dependency footprint is intentionally minimal (Pydantic for data validation, ReportLab for PDF generation) so that the application can be deployed on any machine or low-cost cloud instance without a database server.

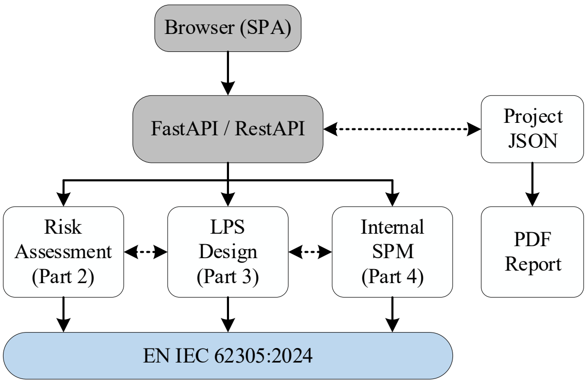

Fig. 1. LPT system architecture. The browser SPA communicates with the FastAPI back end, which dispatches to three calculation modules. Each module directly implements the EN IEC 62305:2024 tables and equations. Projects are persisted as JSON; PDF reports are generated on demand.

The tool is organised into three modules that correspond to the main assessment tasks defined in EN IEC 62305:2024.

A. Risk Assessment Module (Part 2)

This module implements functionalities per EN IEC 62305-2:2024, Annex A (collection areas and annual dangerous event frequencies), Annex B (probability and reduction factors), Annex C (loss factors), Table 3 (all 16 risk components), and the two compliance criteria of Table 1: $R_{L1} \leq R_{T,L1} = 10^{-5}\,\text{yr}^{-1}$ and $R_{L2} \leq R_{T,L2} = 10^{-3}\,\text{yr}^{-1}$. The frequency-of-damage criterion ($F \leq F_T$) introduced in Part 2 Clause 9 is also evaluated. An arbitrary number of named risk zones can be defined, each with its own loss profile. The tool then aggregates per-zone components into structure-level risk totals. Multiple service lines (LV power, HV power, telecom, signal/data) are supported, each with per-section installation and environment factors.

B. External LPS Design Module (Part 3)

Given the LPS class established by the risk assessment (or manually overridden), this module applies EN IEC 62305-3:2024 to produce: rolling sphere radius, mesh cell size, and protection-angle results for air termination (standard, Table 2), minimum down-conductor count and spacing (standard, Table 5), earth electrode sizing for Type A and Type B arrangements (standard, Figure 5), separation distance at user-specified check points (standard, Eq. 6), and complete material dimension tables for conductors above and below ground (standard, Tables 6 and 7). Figure 2 shows a 3D representation of the rolling sphere method applied to an example building. The rolling sphere radius is $r = 20\,\text{m}$ corresponding to a Class I LPS.

C. Internal SPM Module (Part 4)

This module implements Annex C of EN IEC 62305-4:2024 to determine the Lightning Protection Zone (LPZ) hierarchy and to generate a coordinated SPD system specification. It produces impulse current ratings and connection

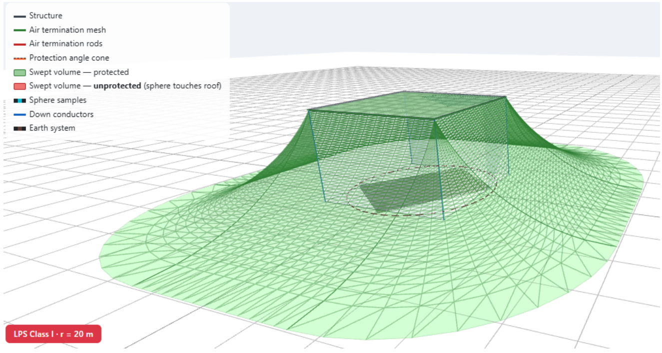

Fig. 2. Example of a 3D representation of the rolling sphere applied in LPT.

types for Class I (main board, LPZ $0 \rightarrow 1$), Class II (sub-board, LPZ $1 \rightarrow 2$, optional), and Class III (near-equipment) devices for power, telecom, and signal lines, together with the minimum bonding-conductor cross-sections at each boundary from Table 1 of Part 4 in the standard.

D. Calculation Traceability

Each calculation is implemented as a pure Python function whose docstring cites the relevant standard equation or table. For example, the collection area for flashes to a rectangular structure is coded directly from Eq. (A.3) in the standard EN IEC 62305-2:2024:

$$A_D = LW + 6H(L + W) + 9\pi H^2, \tag{1}$$

and the annual number of dangerous events from Eq. (A.5):

$$N_D = N_{SG} \cdot A_D \cdot C_D \cdot 10^{-6}. \tag{2}$$

This one-to-one mapping between code and standard equation simplifies independent verification and future maintenance when the standard is revised.

The tool performs input validation before executing any calculation. Required fields (structure dimensions, lightning ground flash density, and at least one service line) are checked for completeness; numerical ranges are enforced against the limits implied by the standard (for example, $N_G > 0$, $0 < P_P \leq 1$, $L, W, H > 0$). Invalid or missing inputs produce descriptive error messages that identify the offending field, preventing the submission of a partially specified project. The report generator is invoked only after a successful assessment run, ensuring that every exported PDF contains a complete and consistent set of inputs and results. LPT is currently deployed as a locally hosted application; public availability is under consideration for a future release.

III. Benchmark Methodology

Annex F of EN IEC 62305-2:2024 (informative) presents three worked examples with fully specified input data and tabulated intermediate and final results. These case studies are the standard body's own reference for confirming the correctness of a risk assessment implementation. For each case study:

1) The input parameters listed in Annex F Tables are entered into LPT exactly as given, with no additional assumptions.

TABLE I
HOUSE CASE STUDY — KEY INPUT PARAMETERS (ANNEX F TABLE F.1)

Parameter	Symbol	Value
Strike-point density	N_{SG}	8.0 $\text{km}^{-2}\text{yr}^{-1}$
Dimensions (L, W, H)		15 m × 20 m × 6 m
Location factor	C_D	1 (isolated)
Construction	P_S	1 (masonry)
Environment	C_E	1 (rural)
Existing LPS	P_{LPS}	1 (none)
Power line length		1 000 m, aerial
Telecom line length		800 m, aerial
Withstand voltage (power / telecom)	U_W	2.5 / 1.5 kV
Floor surface	r_t	10^{-5} (linoleum)
Fire risk factor	r_f	10^{-3}
Person presence	P_P	0.5

2) LPT is executed and all computed intermediate values (collection areas, annual event frequencies, per-zone risk components, and total risks) are recorded.
3) The LPT values are compared against the reference values tabulated in Annex F.

The Annex F note states that *"owing to rounded values used for calculation, one can obtain slightly different results"*. Accordingly, the verification criterion adopted here is agreement to three significant figures for non-negligible components, consistent with the precision used in the Annex F tables. Values stated as ≈ 0 in the standard are treated as zero in the comparison. The primary conformance criterion in all cases is agreement of the compliance verdict: whether $R \leq R_T$ and $F \leq F_T$, rather than digit-for-digit reproduction of intermediate values.

IV. BENCHMARK RESULTS

A. Case Study F.2 — House

The house is an isolated rural structure on flat ground with no existing protection, fed by one aerial LV power line and one aerial telecom line (Table I). Only zone Z_2 (interior) is assessed for risk. The exterior zone is excluded because the house is inhabited only six months per year and persons are assumed to be indoors during thunderstorms ($P_P = 0.5$).

Table II compares the collection areas and annual dangerous event frequencies computed by LPT with the reference values from Annex F Tables F.4 and F.5. All values agree to the precision stated in the standard.

Table III presents the risk components for zone Z_2, both for the unprotected structure and after installing LPL IV SPDs on both service lines at the building entry point. The standard concludes that the unprotected risk $R = 1.793 \times 10^{-5}\,\text{yr}^{-1}$ exceeds the tolerable threshold $R_T = 10^{-5}\,\text{yr}^{-1}$, and that SPD installation reduces the risk to $R = 0.149 \times 10^{-5}\,\text{yr}^{-1}$, which is compliant. LPT reproduces both findings, with a small difference to the third decimal.

B. Case Study F.3 — Office Building

The office building is a five-zone reinforced concrete structure ($L = 20\,\text{m}$, $W = 40\,\text{m}$, $H = 25\,\text{m}$) in a suburban environment with $N_{SG} = 4\,\text{km}^{-2}\text{yr}^{-1}$. It is served by a buried HV/LV power line (1 000 m HV section, 100 m LV section) and an external fibre-optic telecom cable (no flash

TABLE II
HOUSE — COLLECTION AREAS AND ANNUAL DANGEROUS EVENTS: LPT VS. EN IEC 62305-2:2024 ANNEX F REFERENCE VALUES

Quantity	Standard (ref.)	LPT
A_D (m^2)	2.58×10^3	2.58×10^3
A_M (m^2)	1.87×10^5	1.87×10^5
A_{LP} (m^2)	4.00×10^4	4.00×10^4
A_{IP} (m^2)	7.69×10^5	7.69×10^5
A_{LT} (m^2)	3.20×10^4	3.20×10^4
A_{IT} (m^2)	1.54×10^6	1.54×10^6
N_D (yr^{-1})	2.06×10^{-2}	2.06×10^{-2}
N_M (yr^{-1})	7.50×10^{-1}	7.50×10^{-1}
N_{LP} (yr^{-1})	3.20×10^{-1}	3.20×10^{-1}
N_{IP} (yr^{-1})	3.07	3.08
N_{LT} (yr^{-1})	2.56×10^{-1}	2.56×10^{-1}
N_{IT} (yr^{-1})	6.17	6.17

TABLE III
HOUSE — RISK COMPONENTS FOR ZONE Z_2 ($\times 10^{-5}$ YR^{-1}): LPT VS. ANNEX F TABLES F.8 AND F.9

	Unprotected		Protected (SPD LPL IV)	
Component	Std.	LPT	Std.	LPT
R_B	0.062	0.062	0.062	0.062
R_U	0.003	≈ 0	≈ 0	≈ 0
R_V	1.728	1.728	0.086	0.086
R	1.793	1.790	0.149	0.148
R_T			1.0	
Compliant?	No		Yes	

exposure, $A_{LT} = A_{IT} = 0$). Five zones are defined: Z_1 (entrance, outside), Z_2 (roof), Z_3 (archive, high fire risk), Z_4 (offices), and Z_5 (computer centre).

Table IV summarises the total risk per zone before and after protection, alongside the corresponding LPT values and the Annex F reference (Tables F.21 and F.23). The protection measures installed are an LPL II external LPS combined with LPL II SPDs on the power line at the building entry point.

The standard identifies zones Z_2 and Z_3 as non-compliant in the unprotected case. After applying LPL II protection, all zones satisfy $R \leq R_T$. LPT produces identical verdicts. The frequency-of-damage assessment (Annex F Tables F.22 and F.24) is similarly reproduced: the unprotected structure has $F = 0.584\,\text{yr}^{-1}$ against $F_T = 5 \times 10^{-2}\,\text{yr}^{-1}$, and the LPL II coordinated SPD system reduces this to $F = 0.014\,\text{yr}^{-1}$. LPT calculates $F = 0.0138\,\text{yr}^{-1}$, which is compliant.

C. Case Study F.4 — Hospital

The hospital is the most complex of the three case studies, with five zones including a rooms block (Z_3), an operating block (Z_4), and an intensive care unit (Z_5), over a reinforced concrete structure ($50\,\text{m} \times 150\,\text{m} \times 10\,\text{m}$) with $N_{SG} = 8\,\text{km}^{-2}\text{yr}^{-1}$. Because critical care equipment is present, the loss factors L_{O1} are non-zero, which activates the R_C, R_M, R_W, and R_Z risk components that are zero for the house and office cases. This substantially increases the unprotected risk, with zone Z_5 reaching $R = 306.787 \times 10^{-5}$, more than 300 times the tolerable limit.

TABLE IV
OFFICE BUILDING — TOTAL RISK R PER ZONE ($\times 10^{-5}$ YR^{-1}): LPT VS. ANNEX F TABLES F.21 AND F.23

	Unprotected		Protected	
Zone	Std.	LPT	Std.	LPT
Z_1 (entrance)	0.002	0.001	≈ 0	≈ 0
Z_2 (roof)	2.259	2.260	0.113	0.113
Z_3 (archive)	6.526	6.526	0.592	0.592
Z_4 (offices)	0.202	0.202	0.018	0.018
Z_5 (comp. ctr.)	0.156	0.156	0.014	0.014
R_T	1.0			

TABLE V
HOSPITAL — TOTAL RISK R PER ZONE ($\times 10^{-5}$ YR^{-1}): LPT VS. ANNEX F TABLES F.35 AND F.37

	Unprotected		Protected	
Zone	Std.	LPT	Std.	LPT
Z_1 (outside)	0.036	0.036	0.002	0.002
Z_2 (roof)	18.357	18.37	0.092	0.093
Z_3 (rooms blk)	36.528	36.53	0.692	0.692
Z_4 (oper. blk)	108.834	108.8	0.266	0.266
Z_5 (ICU)	306.787	306.8	0.685	0.685
R_T	1.0			

Table V shows the zone-level risk comparison. The required protection package (LPS class II, warning signs on the roof, plus a zone-differentiated coordinated SPD system with $P_{SPD} = 0.01$ for Z_3 and $P_{SPD} = 0.002$ for Z_4 and Z_5) brings all zones to compliance.

Additionally Fig. 3 shows a per-zone risk component breakdown table from the LPT interface with the compliance verdict (pass-green/fail-red). This directly illustrates what the benchmarked output looks like in practice.

To illustrate the dominant components driving the hospital risk, Table VI details the unprotected risk breakdown for the three inner zones, comparing LPT output with the Annex F reference (Table F.35). The R_C and R_Z components, driven by the hospital-specific non-zero L_{O1} loss factor, account for more than 85 % of the total risk in zones Z_4 and Z_5, underlining the need for a coordinated SPD system as the primary protection measure.

The frequency-of-damage benchmark (Annex F Tables F.36 and F.38) is likewise reproduced correctly: the unprotected structure has $F = 0.325\,\mathrm{yr}^{-1}$ in zone Z_3 against $F_T = 0.05\,\mathrm{yr}^{-1}$, and $F = 0.306\,\mathrm{yr}^{-1}$ in zones Z_4 and Z_5 against $F_T = 0.01\,\mathrm{yr}^{-1}$. After protection, LPT computes $F = 0.014\,\mathrm{yr}^{-1}$ for all three zones for the inner-systems frequency components, matching the Annex F reference.

V. DISCUSSION

A. Conformance Summary

Across all three case studies and all tabulated intermediate and final values, LPT produces results that agree with the Annex F reference. The small numerical differences that do appear are attributable to rounding in the intermediate steps of the standard's own worked examples, not to errors in the LPT implementation. All compliance verdicts (pass/fail for both the risk and frequency-of-damage criteria) are reproduced exactly.

TABLE VI
HOSPITAL — DETAILED RISK COMPONENTS FOR INNER ZONES, UNPROTECTED ($\times 10^{-5}$ YR^{-1}): LPT VS. ANNEX F TABLE F.35

	Z_3 (rooms)		Z_4 (oper.)		Z_5 (ICU)	
Comp.	Std.	LPT	Std.	LPT	Std.	LPT
R_B	3.572	3.572	0.484	0.484	0.714	0.714
R_C	17.862	17.86	63.213	63.21	178.619	178.6
R_M	1.881	1.881	0.017	0.017	0.047	0.047
R_V	0.480	0.480	0.065	0.065	0.096	0.096
R_W	1.200	1.200	4.247	4.247	12.000	12.000
R_Z	11.531	11.53	40.807	40.81	115.308	115.3
R	36.528	36.53	108.834	108.8	306.787	306.8

The three Annex F case studies span the full practical range of structures addressed by the standard: a simple single-zone residential building, a multi-zone commercial building with mixed fire risk, and a critical healthcare facility with zone-differentiated LEMP protection requirements. Together they exercise every implemented risk component and protection measure, providing broad coverage of the tool's calculation logic within the scope of isolated rectangular structures.

B. 2024 Edition Differences

The 2024 edition of EN IEC 62305-2 differs from the widely used 2010 edition in several respects that are fully incorporated in LPT. The most significant are the replacement of the isokeraunic-map-derived N_G by the direct lightning location system (LLS) parameter N_{SG} as the primary input (with $N_{SG} \approx 2N_G$ as a fallback conversion), the inclusion of the TWS probability reduction factor P_{TWS}, and the explicit treatment of the frequency-of-damage criterion F as a co-equal compliance check alongside the risk criterion R. All three changes are implemented in LPT.

C. Scope and Limitations

LPT is currently scoped to isolated rectangular structures on approximately flat ground. The N_{DJ} term (dangerous events from flashes to adjacent structures) is not computed, and very tall structures requiring height-correction to N_D, structures on hillsides, and distributed systems (pipelines, rail networks) are outside the present scope.

Within the implemented scope, the three modules have different levels of maturity. The risk assessment module is the most complete: it has been verified against all three Annex F case studies and handles the full range of structures covered by the standard, from simple single-zone buildings to multi-zone critical facilities with zone-differentiated protection levels. The external LPS design module covers the principal sizing outputs of EN IEC 62305-3: air termination, down-conductor spacing, earth termination, and separation distance, but does not automate the natural component assessment of reinforced concrete frameworks, which requires manual verification by the designer per §5.3. The internal SPM module provides SPD selection guidance using the simplified

Risk Components by Zone — Table 3 (Tables F.8/F.9 style) All values $\times 10^0$ /yr — red=L1 (human life), orange=L2 (physical damage)

Zone/Type	RAT	RAD	RB_1	RC_1	RM_1	RU	RV_1	RW_1	RZ_1	RB_2	RC_2	RM_2	RV_2	RW_2	RZ_2	Zone R = RL1+RL2
Zone: Z4																
L1 type (human life)	6.321e-9	—	1.264e-6	6.321e-4	1.664e-7	—	1.699e-7	4.247e-5	4.081e-4							0.001084
L2 type (phys. damage)										3.572e-6	—	—	4.800e-7	—	—	4.052e-6
															Zone R = RL1+RL2	**0.001088**
Zone: Z5																
L1 type (human life)	1.786e-8	—	3.572e-6	0.001786	4.703e-7	—	4.800e-7	1.200e-4	0.001153							0.003064
L2 type (phys. damage)										3.572e-6	—	—	4.800e-7	—	—	4.052e-6
															Zone R = RL1+RL2	**0.003068**
Zone: Z1																
L1 type (human life)	3.568e-7	—	—	—	—	—	—	—	—							3.568e-7
L2 type (phys. damage)										—	—	—	—	—	—	0
															Zone R = RL1+RL2	**3.568e-7**
Zone: Z2																
L1 type (human life)	1.835e-7	1.835e-4	—	—	—	—	—	—	—							1.837e-4
L2 type (phys. damage)										—	—	—	—	—	—	0
															Zone R = RL1+RL2	**1.837e-4**
Zone: Z3																
L1 type (human life)	1.786e-8	—	1.786e-5	1.786e-4	1.881e-5	—	2.400e-6	1.200e-5	1.153e-4							3.450e-4
L2 type (phys. damage)										1.786e-5	—	—	2.400e-6	—	—	2.026e-5
															Zone R = RL1+RL2	**3.653e-4**

Fig. 3. Risk assessment results panel in LPT for Hospital case study, unprotected.

probability values of Tables B.7/B.8, which the standard recommends as a first approach; the detailed P_{SPD} verification via Annex D loop-area calculations is not implemented and should be carried out separately for critical installations.

D. Practical Utility

Being web-based, LPT requires no software installation and is accessible from any modern browser. Projects are stored as JSON files that can be version-controlled or exchanged between engineers, and the built-in report generator produces a structured PDF document suitable for submission to regulatory authorities or use as a design basis document. For a practising lightning protection engineer, the tool covers the complete workflow from site data entry through risk assessment to protection measure selection. The risk assessment module in particular eliminates what is otherwise a tedious and error-prone manual process: a multi-zone structure such as the hospital case study in Section IV would require several hours to assess by hand, whereas the tool produces verified results in minutes. The principal professional boundary to communicate to users is that LPT implements the calculation methodology of the standard. It does not replace engineering judgement on site-specific construction details or physical installation design.

VI. Conclusion

This paper presented LPT, a web-based tool implementing the full EN IEC 62305:2024 calculation framework for lightning protection risk assessment (Part 2), external LPS design (Part 3), and internal surge protection measures (Part 4). The tool was benchmarked against the three official case studies in Annex F of EN IEC 62305-2:2024 - a residential house, a multi-zone office building, and a multi-zone hospital - covering both the risk criterion and the frequency-of-damage criterion. In all cases, LPT reproduced the standard's tabulated collection areas, dangerous event frequencies, risk components, and compliance verdicts to within the rounding precision acknowledged by the standard.

The benchmark confirms that LPT can be used with confidence as a conforming computational aid for EN IEC 62305:2024 lightning protection practice. Future work will extend the tool to cover adjacent structures, height correction for tall structures, and the distributed-system case.

Validation against independently constructed real-world case studies is also planned, to complement the Annex F benchmark presented here.

Future developments may also consider integration with broader frameworks, most importantly grounding systems [11].

References

[1] IEC, "EN IEC 62305-1:2024 - Protection against lightning - Part 1: General principles," International Electrotechnical Commission, Geneva, 2024.

[2] IEC, "EN IEC 62305-2:2024 - Protection against lightning - Part 2: Risk management," International Electrotechnical Commission, Geneva, 2024.

[3] IEC, "EN IEC 62305-3:2024 - Protection against lightning - Part 3: Physical damage to structures and life hazard," International Electrotechnical Commission, Geneva, 2024.

[4] IEC, "EN IEC 62305-4:2024 - Protection against lightning - Part 4: Electrical and electronic systems within structures," International Electrotechnical Commission, Geneva, 2024.

[5] V. A. Rakov and M. A. Uman, Lightning: Physics and Effects. Cambridge, UK: Cambridge University Press, 2003.

[6] V. Cooray, Ed., Lightning Protection. London, UK: IET, 2010.

[7] F. Fiamingo, “Lightning protection system design - software tools and methodologies,” in Proc. Int. Conf. on Lightning Protection (ICLP), Vienna, Austria, 2012, pp. 1–6.

[8] A. Smorgonskiy, F. Rachidi, M. Rubinstein, N. Korovkin and A. P. J. van Deursen, “On the use of N_{SG} and N_G in the IEC 62305-2 standard,” Electric Power Systems Research, vol. 113, pp. 75–82, 2014.

[9] C. Gomes and Z. Abdul-Malek, “Practical aspects of risk management using IEC 62305-2,” in Proc. Int. Conf. on Lightning Protection (ICLP), Estoril, Portugal, 2016, pp. 1–8.

[10] S. Ramírez, “FastAPI,” 2019. [Online]. Available: https://fastapi.tiangolo.com

[11] P. Popovski, N. Acevski, and M. Kostov, “Grounding System Analysis Using CAD Assisted Software,” 2024 59th International Scientific Conference on Information, Communication and Energy Systems and Technologies (ICEST), pp. 1–4, Jul. 2024, doi: 10.1109/icest62335.2024.10639632.