PSM Lab
EMI, Earthing & Corrosion

University of Cyprus
Department of Electrical and Computer Engineering

Power System Modelling Laboratory

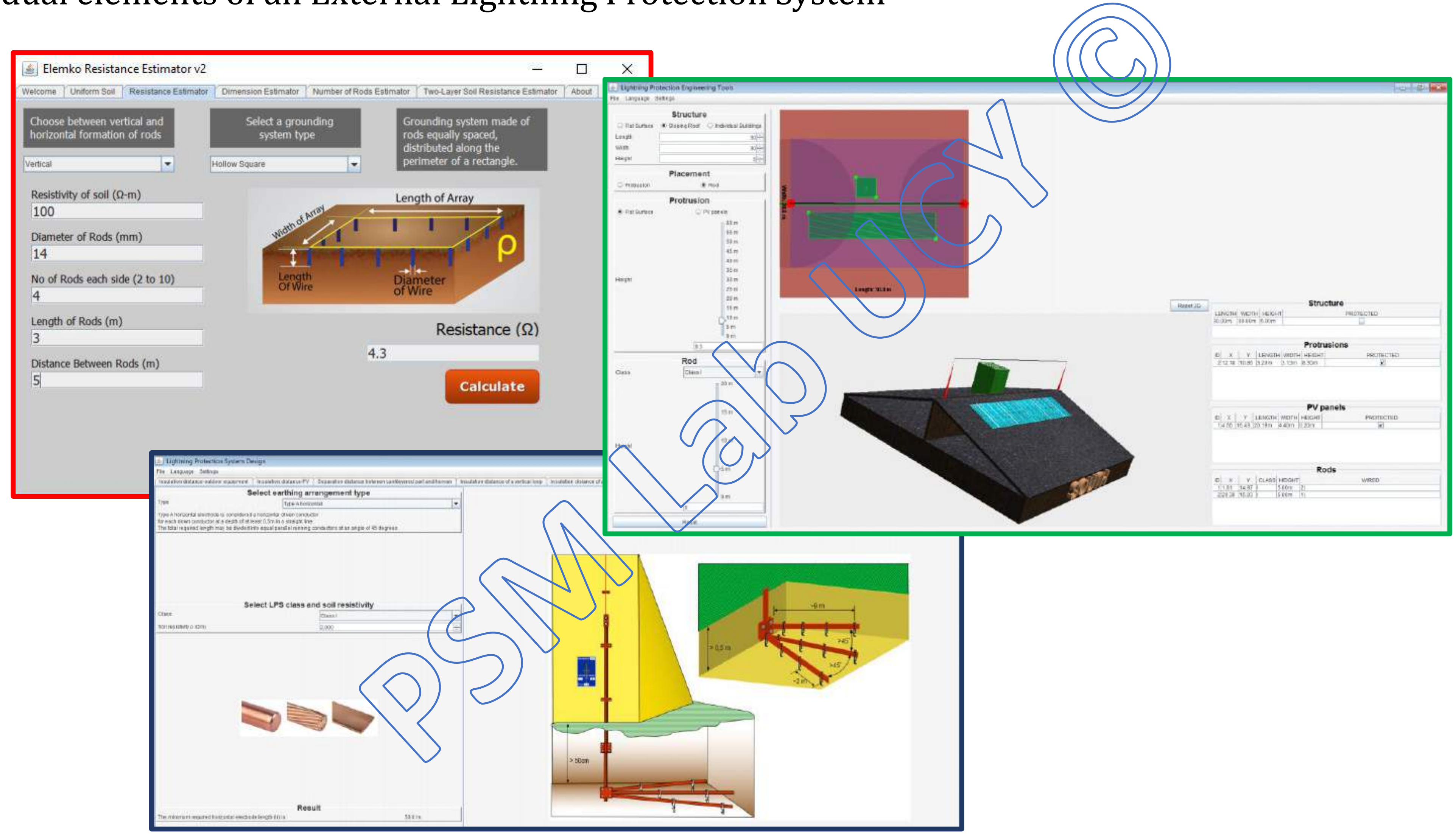
www.psm.ucy.ac.cy

C. A. Charalambous
Assistant Professor
June 2017

Laboratory presentation and software tools

Presentation objectives

- Presentation of 3 software tools directly related to the calculation and evaluation of parameters related to the individual elements of an External Lightning Protection System



Brief Reference to Calculation Tools

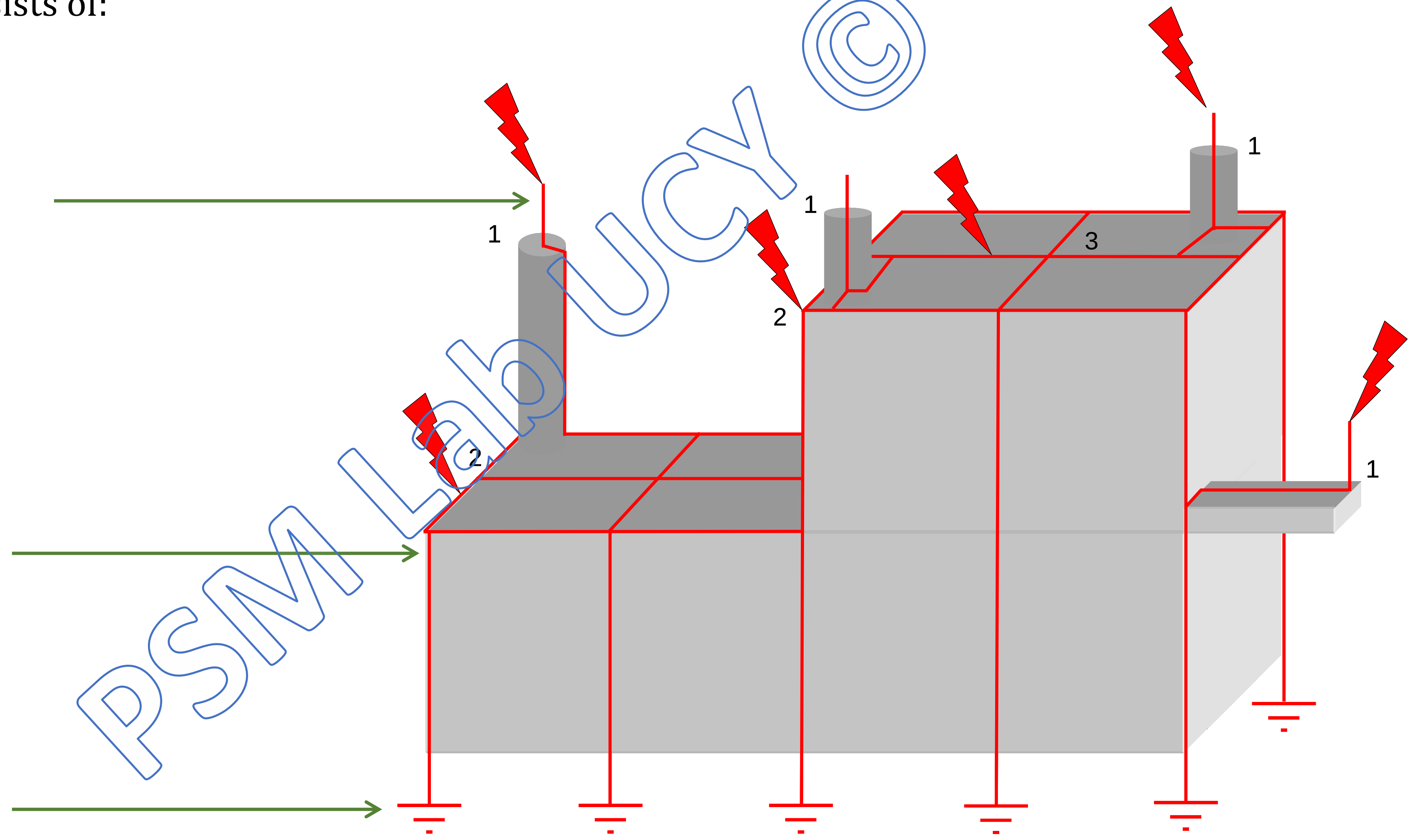
- *Software tools:*
  - They were developed by graduate students of the University of Cyprus, as part of research activities
  - Sponsored by ELEMKO, ABEE
  - Available for free
  - Provide support to Electrical Engineers for relevant studies
  - Use for training and understanding requirements of relevant standard

- *Description:*
  1. Air termination lightning protection system design and assessment tool, IEC 62305-3
  2. Down-conductors and separation distance assessment tool, IEC 62305-3
  3. Earthing Resistance Calculation Tool (BS 7430, IEEE 80)

Software Tools Implementation Background

- According to the existing national, European and international 62305 standard series, an external lightning protection system consists of:

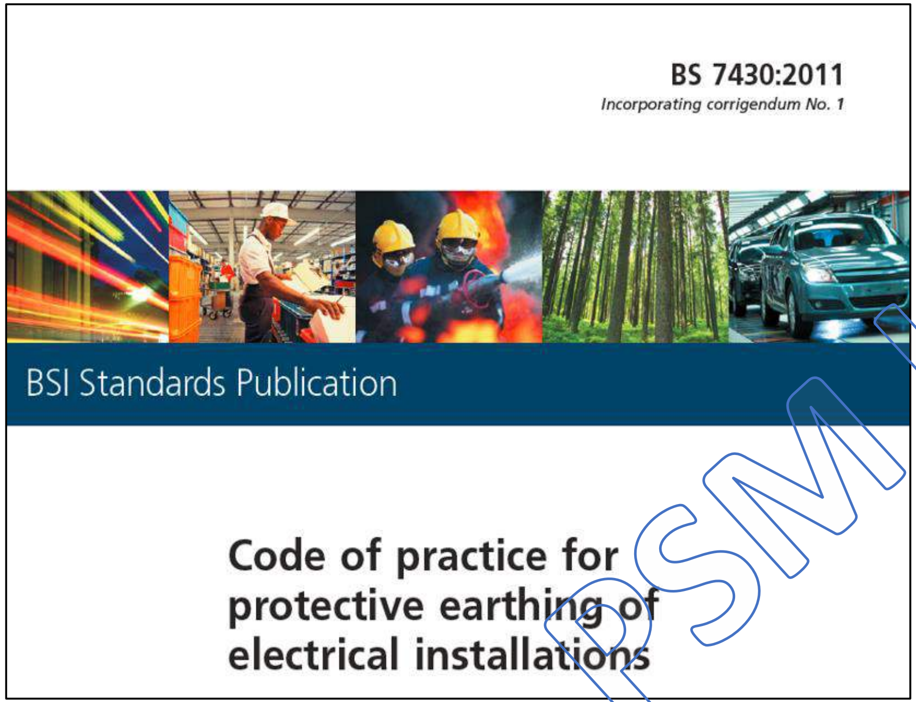
1. Air termination system
2. Down-conductor system
3. Earthing termination system



Earthing Resistance Calculation Tool

Reference to International Standards

- The calculations of the software tool are based on the mathematical equations provided in:
  - ***BS 7430:2011,*** *"Code of practice for protective earthing of electrical installations"*
  - ***IEEE Std 80-2000***, *"IEEE Guide for Safety in AC Substation Grounding"*

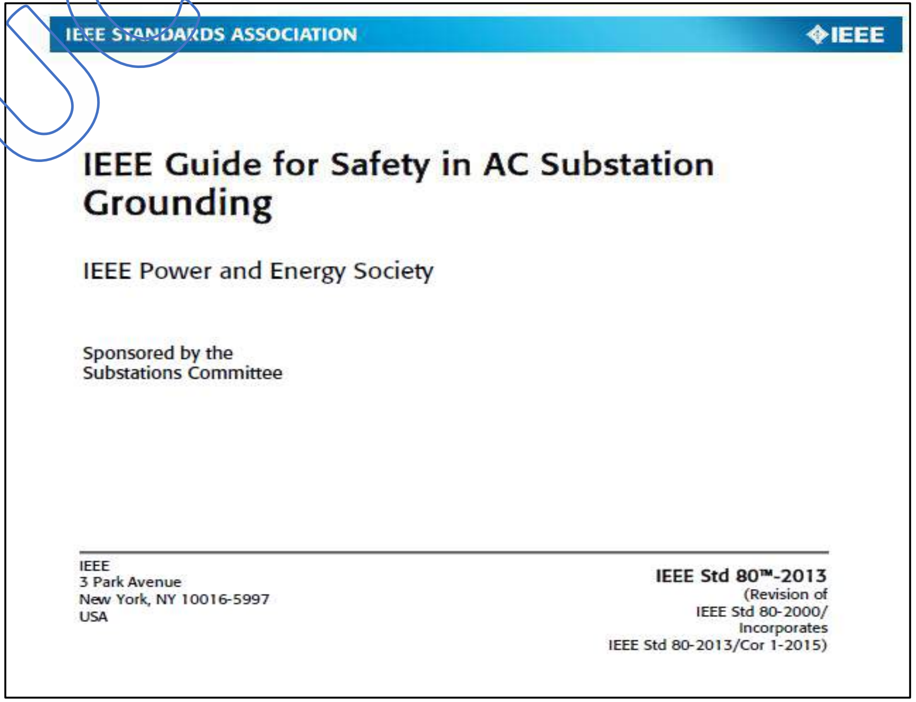


BS 7430:2011

Incorporating corrigendum No. 1

BSI Standards Publication

Code of practice for protective earthing of electrical installations



IEEE STANDARDS ASSOCIATION

IEEE

IEEE Guide for Safety in AC Substation Grounding

IEEE Power and Energy Society

Sponsored by the
Substations Committee

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

IEEE Std 80™-2013
(Revision of
IEEE Std 80-2000/
Incorporates
IEEE Std 80-2013/Cor 1-2015)

Cases studies based on BS 7430: 2011

9.5.3 Rod electrode

The resistance of a rod R_r in ohms (Ω) may be calculated from:

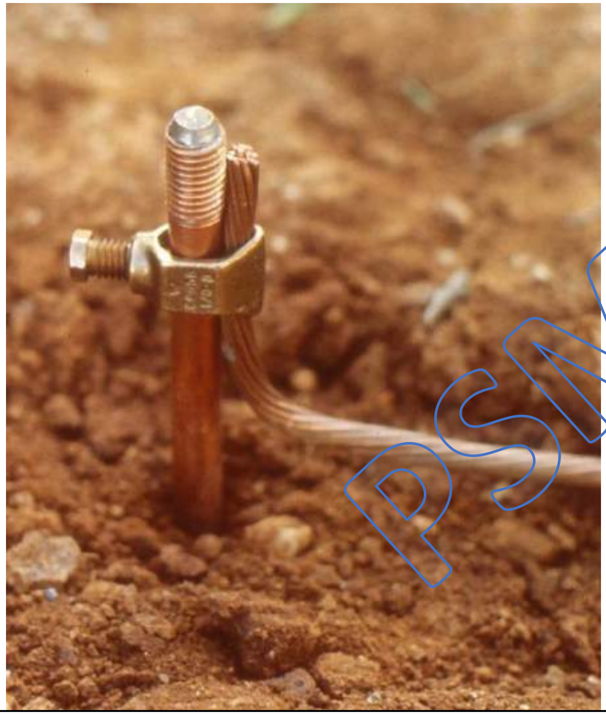
$$R_r = \frac{\rho}{2\pi L}\left[\log_e\left(\frac{8L}{d}\right) - 1\right]$$

where:

ρ is the resistivity of soil, in ohm metres (Ωm);

L is the length of the electrode, in metres (m);

d is the diameter of the rod, in metres (m).



9.5.4 Parallel connection of aligned rods

The resistance R_t in ohms (Ω) of n vertically driven rods set s metres apart may be calculated from:

$$R_t = \frac{1}{n}\frac{\rho}{2\pi L}\left[\log_e\left(\frac{8L}{d}\right) - 1 + \frac{L}{s}\log_e\left(\frac{1.78n}{2.718}\right)\right]$$

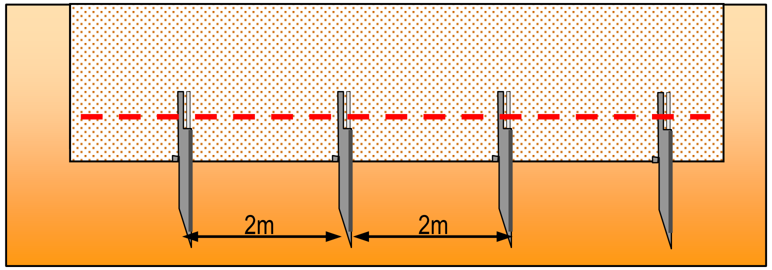
where:

ρ is the resistivity of soil, in ohm metres (Ωm);

L is the length of the electrode, in metres (m);

n is the number of rods;

s is the spacing between the rods, in metres (m).



Cases studies based on BS 7430: 2011

- *The complexity of the equations increases for complicated types of electrode configurations*

9.5.8.5 **C1 Vertical rods in a hollow square**

The resistance R_{TOT} of rods set out in a hollow square [see Figure 15e)] may be claculated from:

$$R_{TOT} = R_r\left(\frac{1+\lambda\rho/2\pi R_1 s}{n}\right)$$

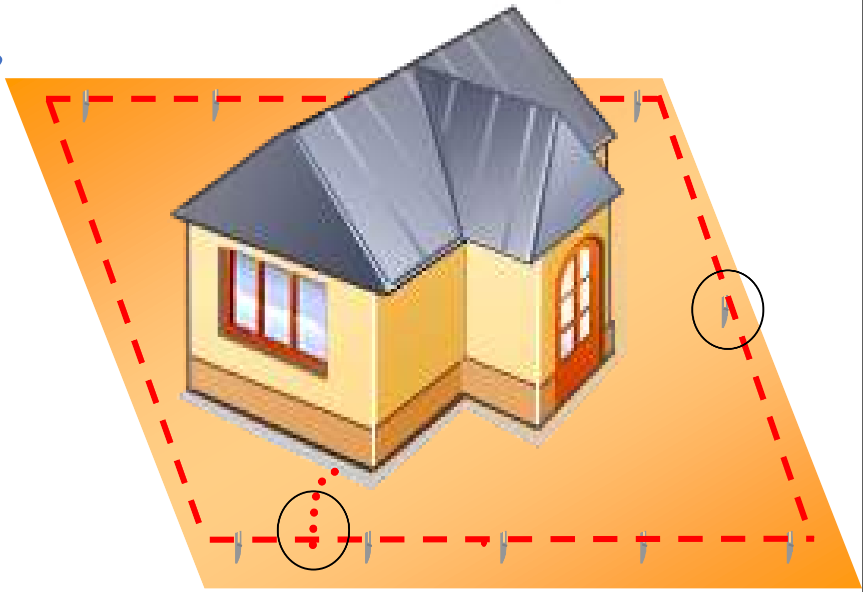
where

- R_r is the resistance of one rod, in oms (Ω);
- λ is the factor in Table 2;
- ρ is the resistivity of soil, in ohm metres (Ωm);
- s is the spacing of rods, in metres (m);
- n is the number of rods used as electrodes (see the note to Table 2).

Table 2 Factors for vertical electrodes arranged in a hollow square

Number of electrodes (n) along the side of the square	Factor λ	Number of electrodes (n) along the side of the square	Factor λ
2	2.71	9	7.65
3	4.51	10	7.90
4	5.46	12	8.22
5	6.14	14	8.67
6	6.63	16	8.95
7	7.03	18	9.22
8	7.30	20	9.40

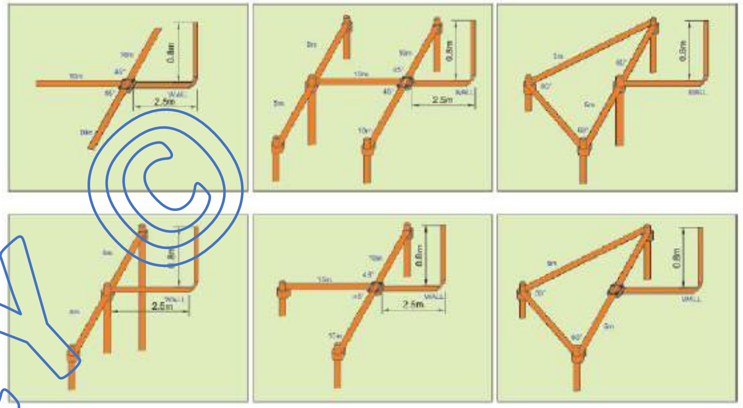
NOTE The number of electrodes around the square is 4(n – 1).

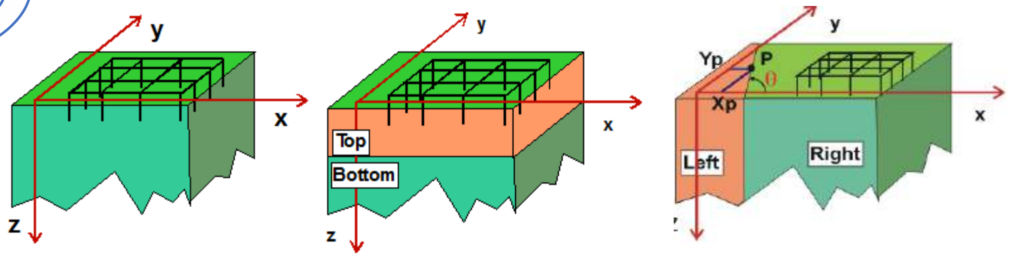


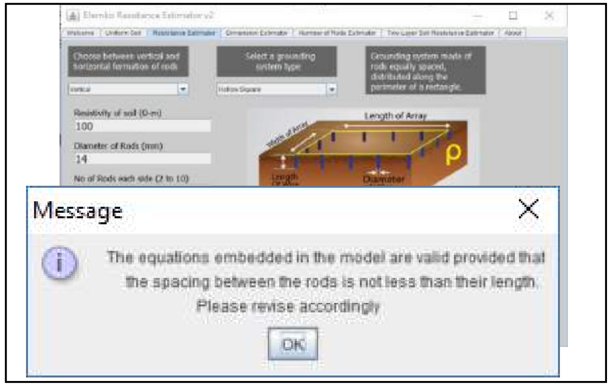
Earthing Resistance Calculation Tool Software Features

- Calculation of earthing resistance for 9 different electrode configurations and types.
- Calculation of electrode dimensions depending on the required value. The calculations are applicable for 9 different configurations and types of electrodes.
- The calculations take into account:
  - The electrodes are placed in uniform soil.
  - The electrodes are placed in multilayer soils (vertical or horizontal separation).

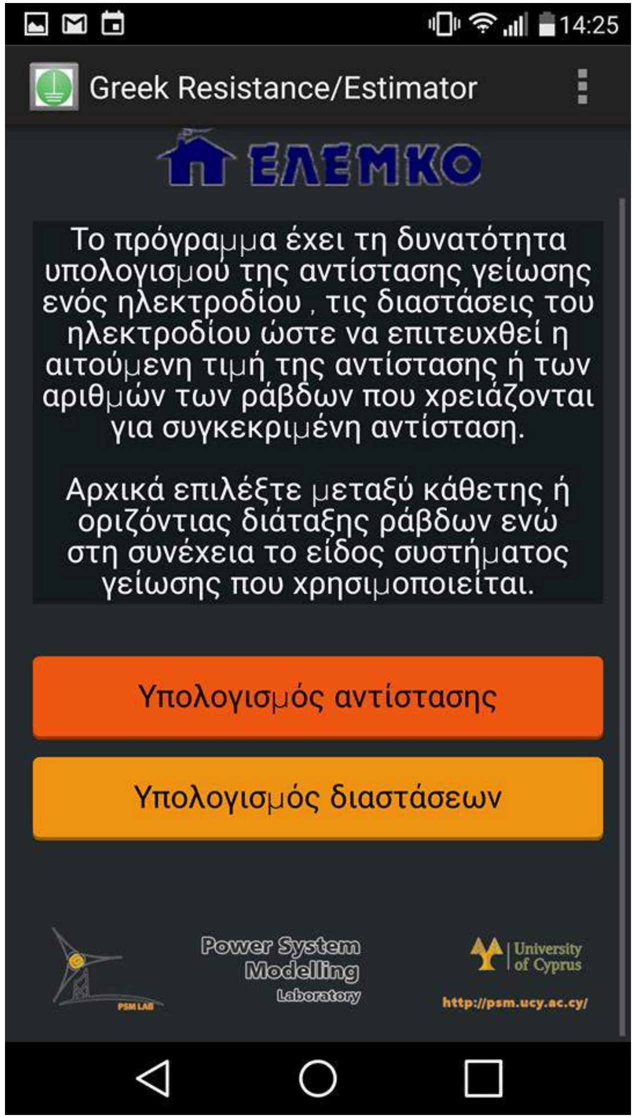
- Calculations taking into account the mathematical constraints of the equations referred in the standards.
  - Where restrictions apply, they are reported in the form of message.



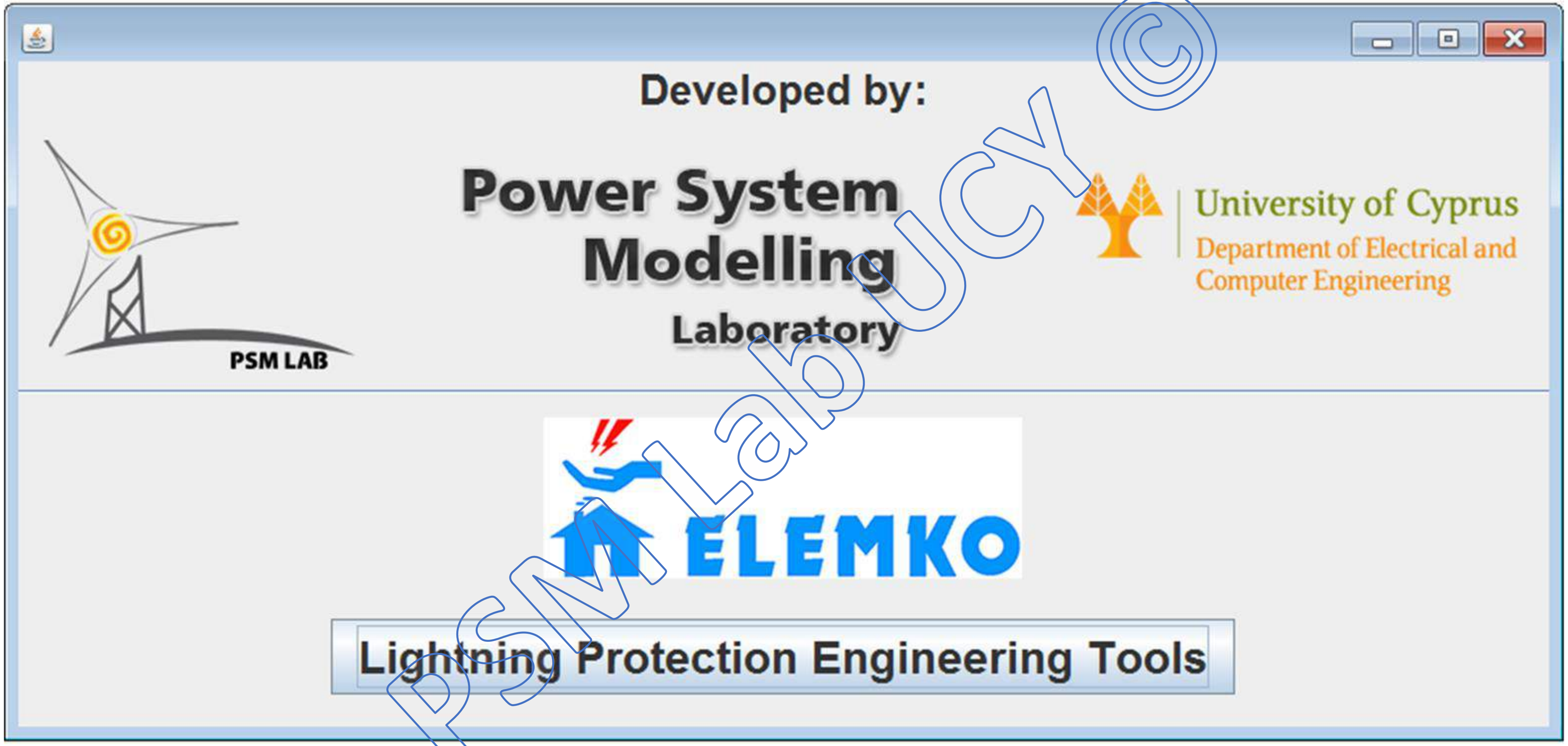




Brief Software Exhibition



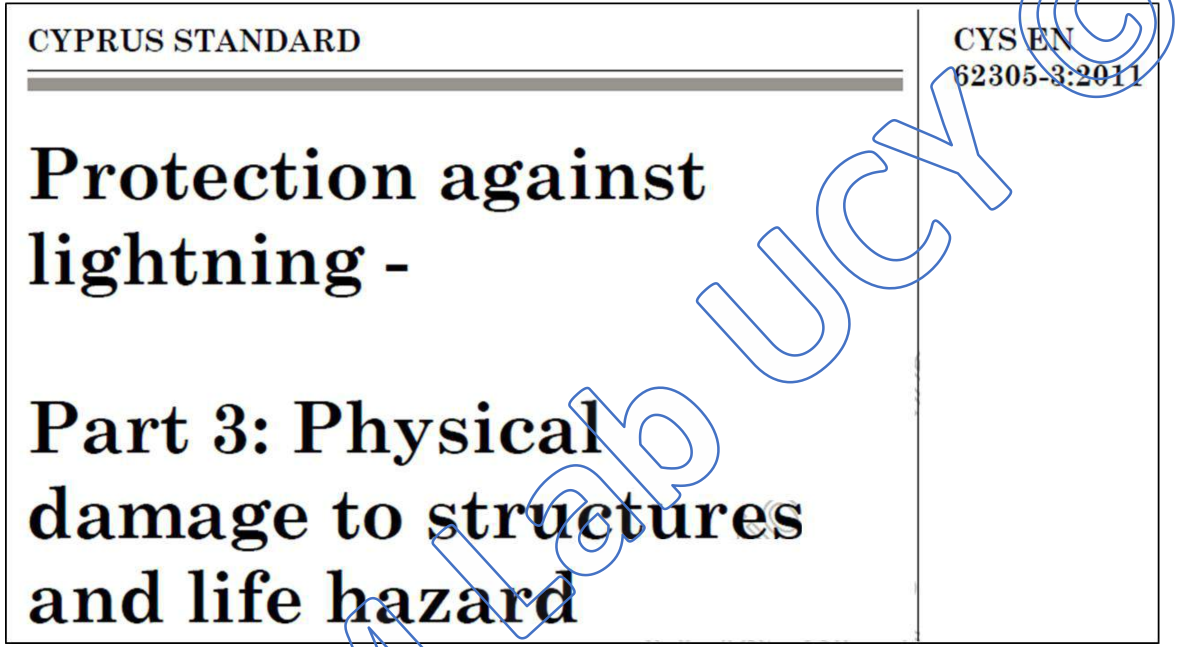
External Lightning Protection Air Termination system design software tool



Reference to International Standards

- ❑ The calculations of the software tool are based on methodologies referred in the standard:

  - ➢ ***EN 62305 -3*** *"Protection Against Lightning – Part 3: Physical damage to structures and life hazard"*



CYPRUS STANDARD

CYS EN 62305-3:2011

Protection against lightning -

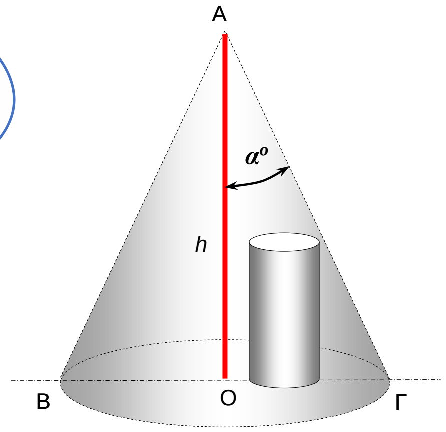
Part 3: Physical damage to structures and life hazard

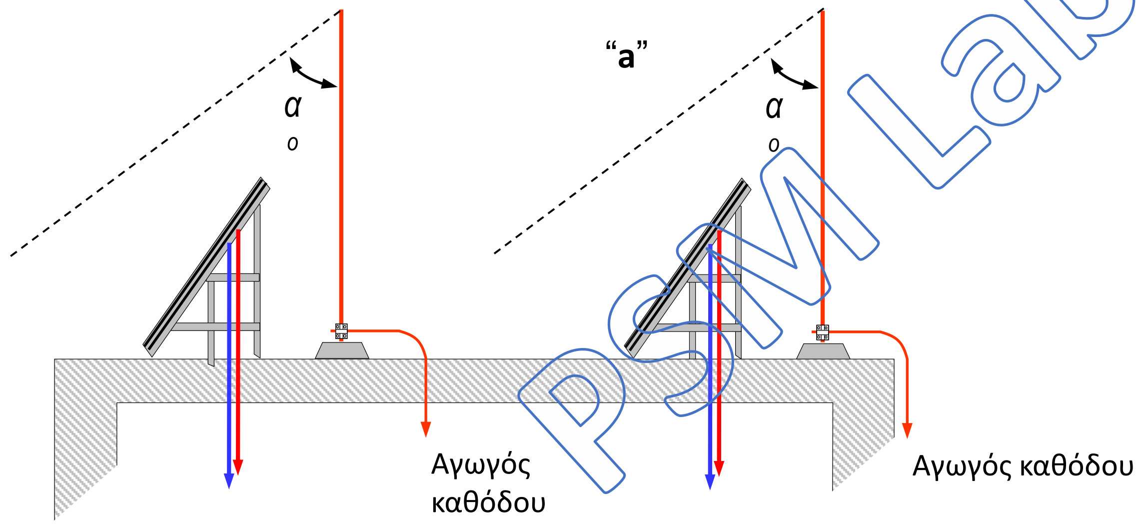
❑ Design of the air termination system:

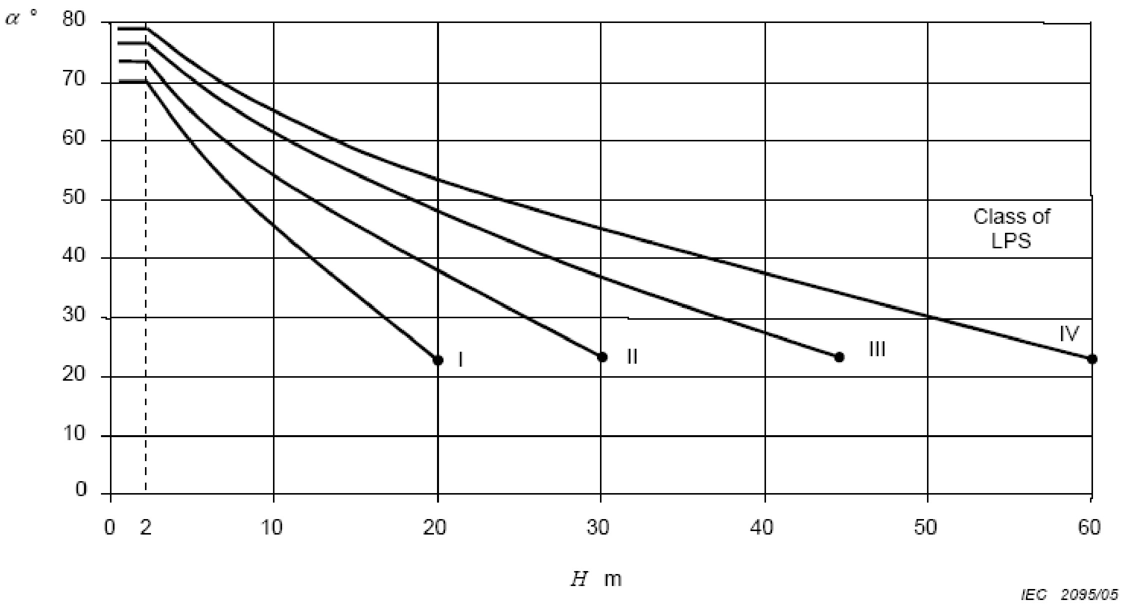
- ➢ *Protection angle method*
- ➢ *Mesh method*
- ➢ *Rolling sphere method*

Air termination design – Protection angle EN 62305-3

- The volume protected by a vertical rod is assumed to have the shape of a right circular cone with the vertex placed on the air-termination axis, semi-apex angle α, depending on the class of LPS, and the height of the air-termination system. As required by the assessment.

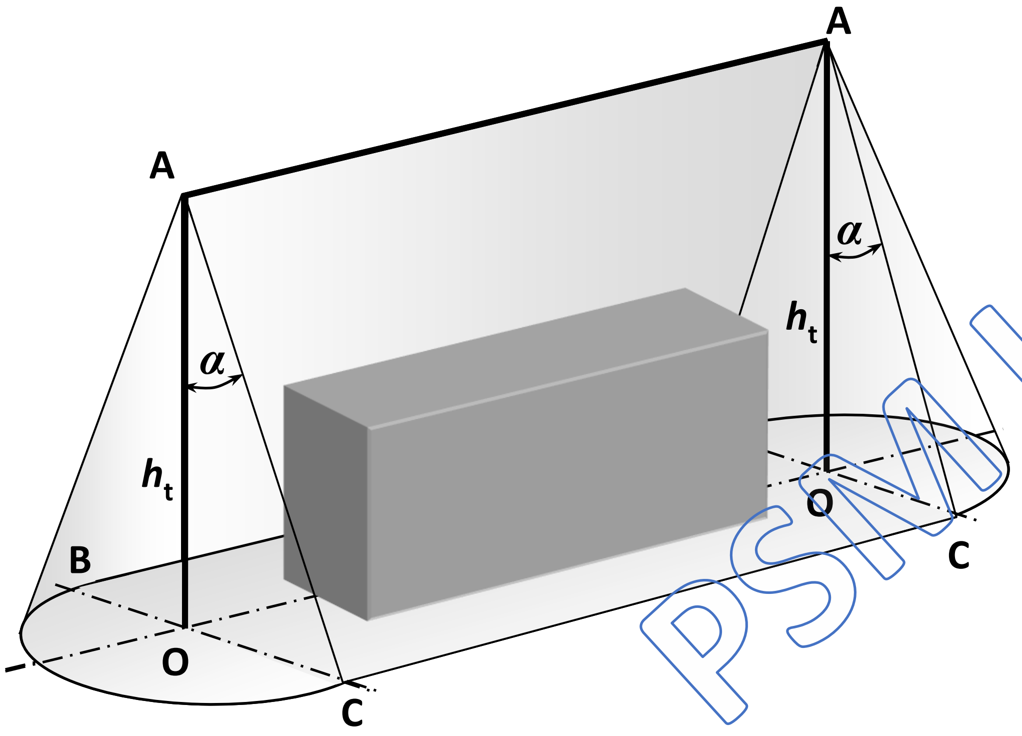


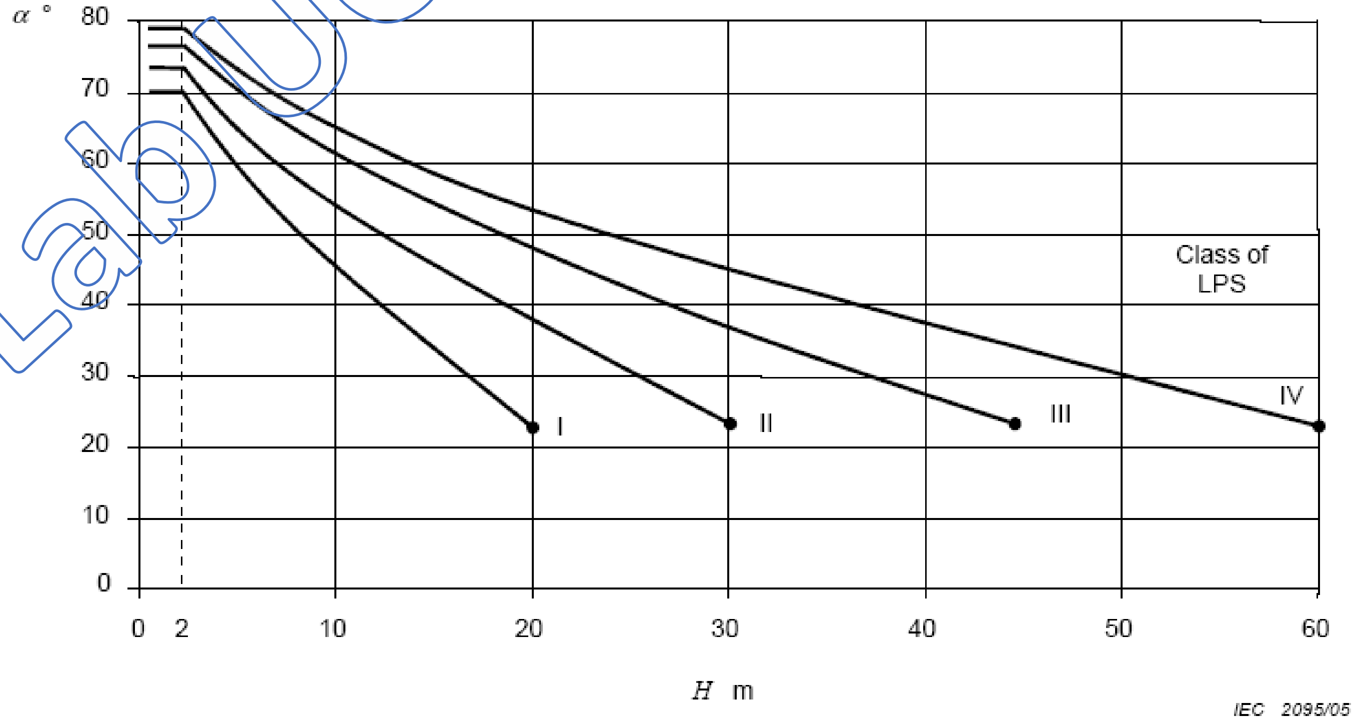




Air termination design – Protection angle with shield wires

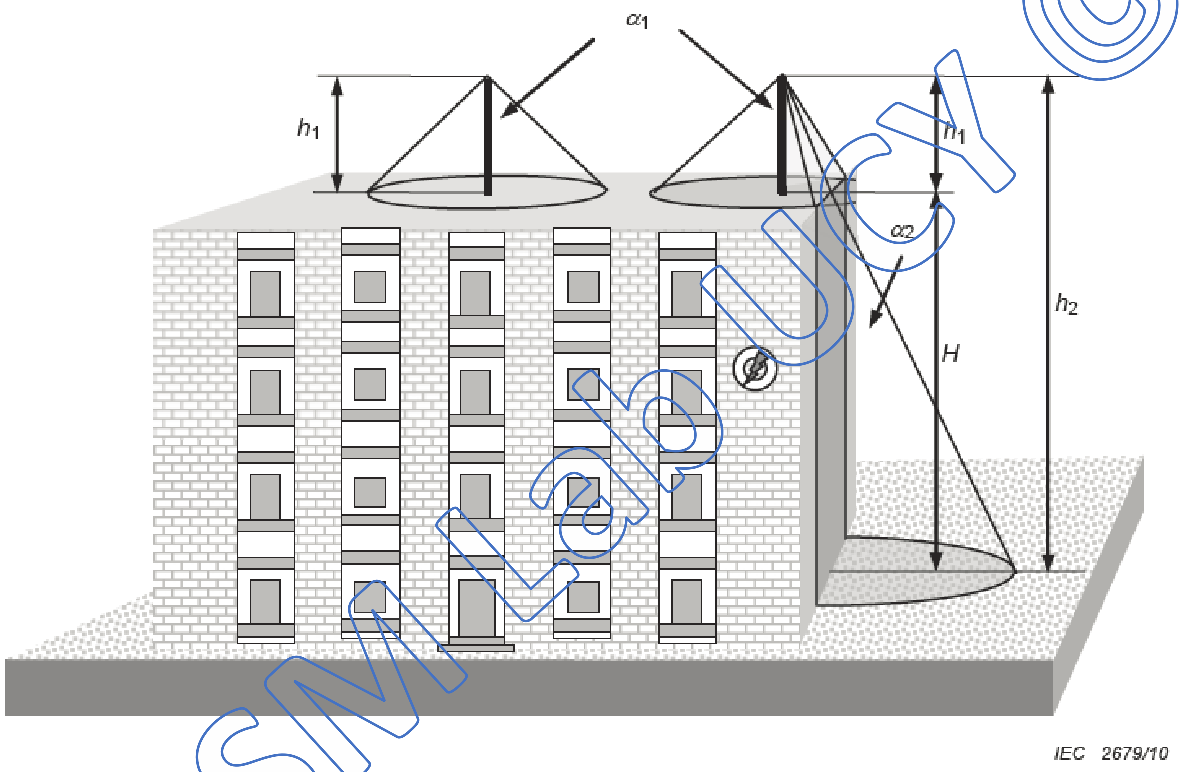
- The volume protected by a wire is defined by the composition of the volume protected by virtual vertical rods having vertexes on the wire. Protection angles vary according to the class of LPS, as resulted from the risk assessment.





Case study: EN 62305-3

- Calculation of protection volume, comprising of a 2-air termination rod on a flat roof. The protection volume is determined by the height of the rod above the examined surface.



Key

H	height of the building over the ground reference plane
h_1	physical height of an air-termination rod
h_2	$h_1 + H$, being the height of the air-termination rod over the ground
α_1	the protection angle corresponding to the air-termination height $h = h_1$, being the height above the roof surface to be measured (reference plane)
α_2	the protection angle corresponds to the height h_2

Case study: EN 62305-3

- Calculation of protection volume on a building with sloped roof protected by air-termination rod. Complex geometrical calculations are required.

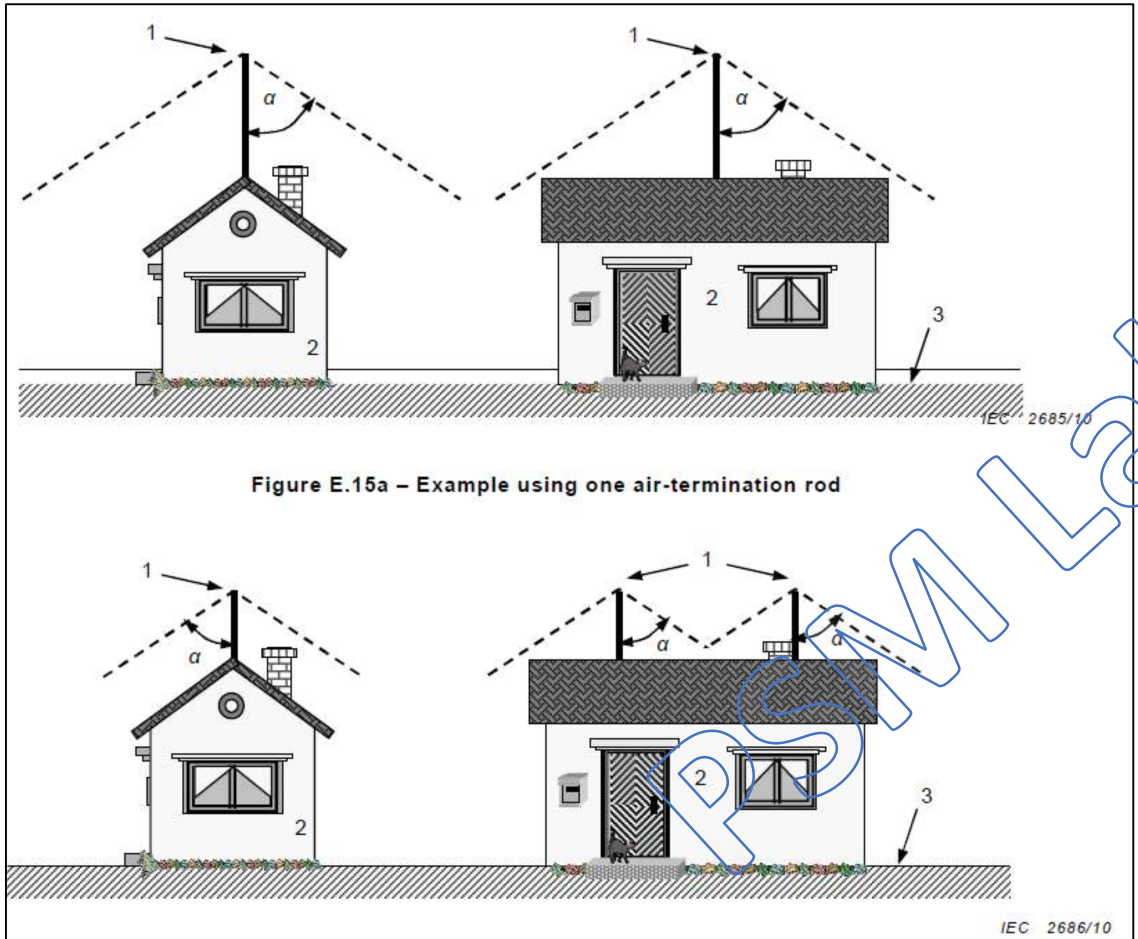
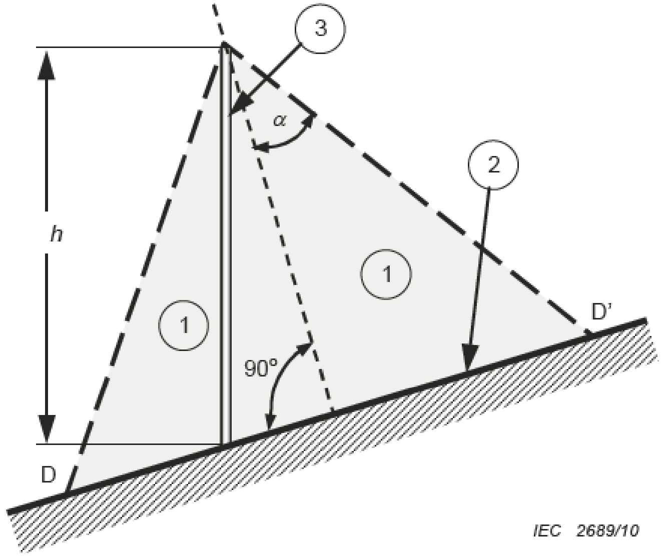


Figure E.15a – Example using one air-termination rod

Figure E.15b – Example using two air-termination rods



Key

1	protected volume
2	reference plane
3	air-termination rod
h	relevant heights of air-termination according to Table 2
α	protection angle
D, D'	limit of the protected area

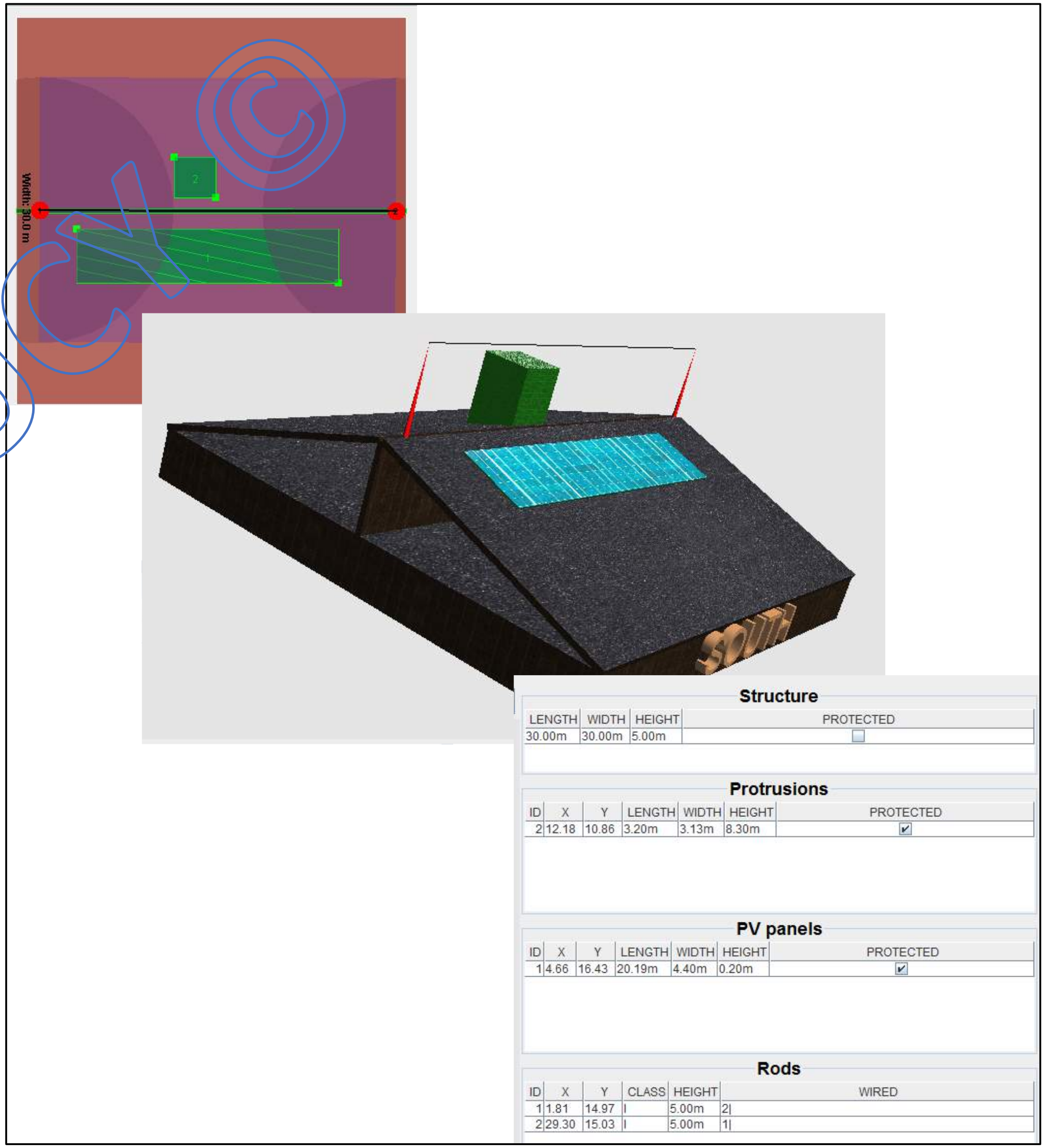
Air-termination External Lightning Protection System Software Tool Features

- Design of air-termination protection angle and protection angle with shield wires

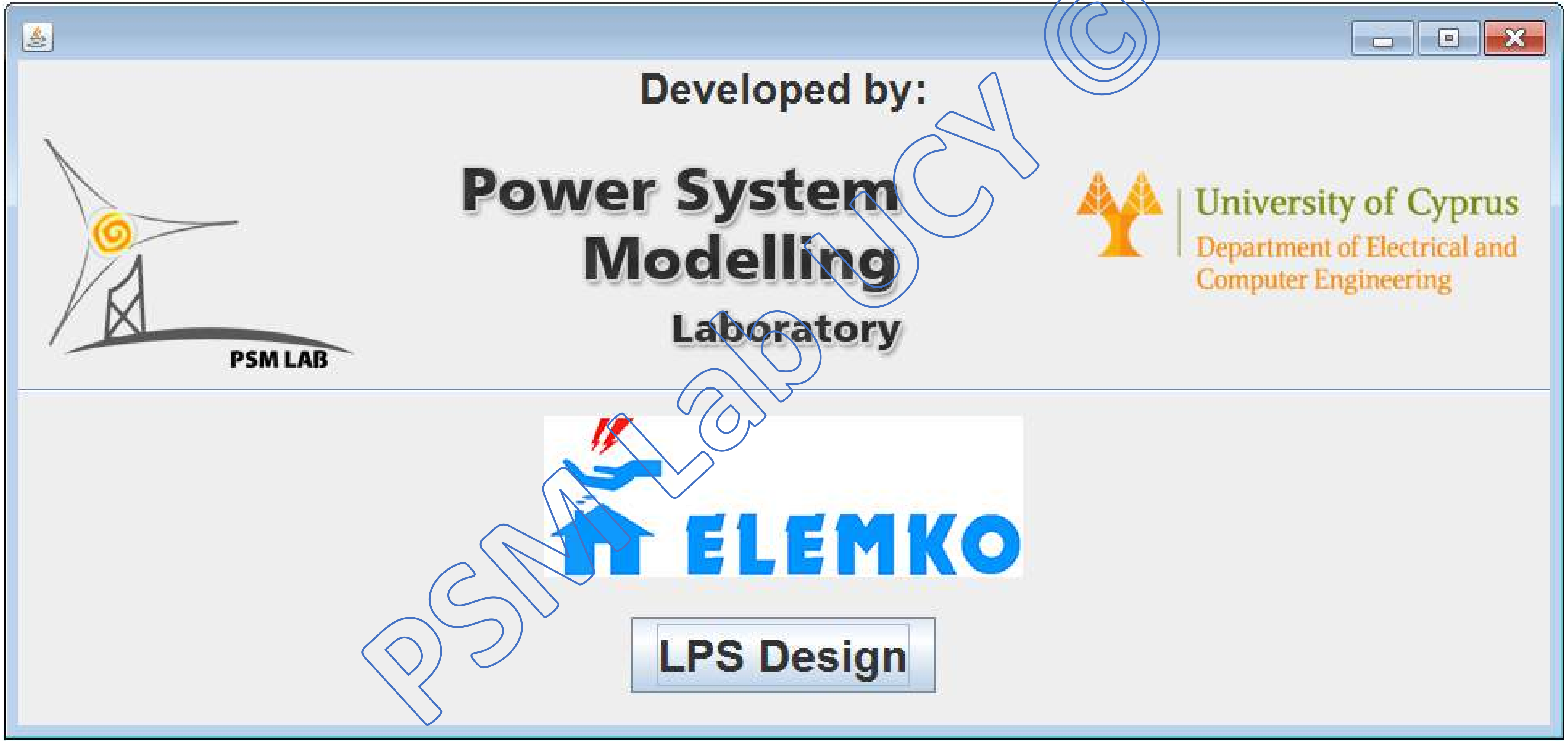
- The software assess:
  - Buildings with flat roof
  - Buildings with slopped roof
  - Buildings with complexes of same and different heights.

- The assessment takes into account:
  - The class of lightning protection system, as resulted from the risk assessment.
  - Building protrusions (i.e. chimneys)
  - Roof PV systems
  - Other roof items/devices that need protection.

- The results are presented:
  - In 2- (top view) and 3-D by visual display
  - In tabulated form with details (i.e . Building dimensions, rods and locations that are considered to be under protection).



Down-conductors and separation distance assessment tool 62305-3



Reference to International Standards

- The calculations of the software tool are based on methodologies referred in the standard:
    - ***EN 62305 -3*** *"Protection Against Lightning – Part 3: Physical damage to structures and life hazard"*

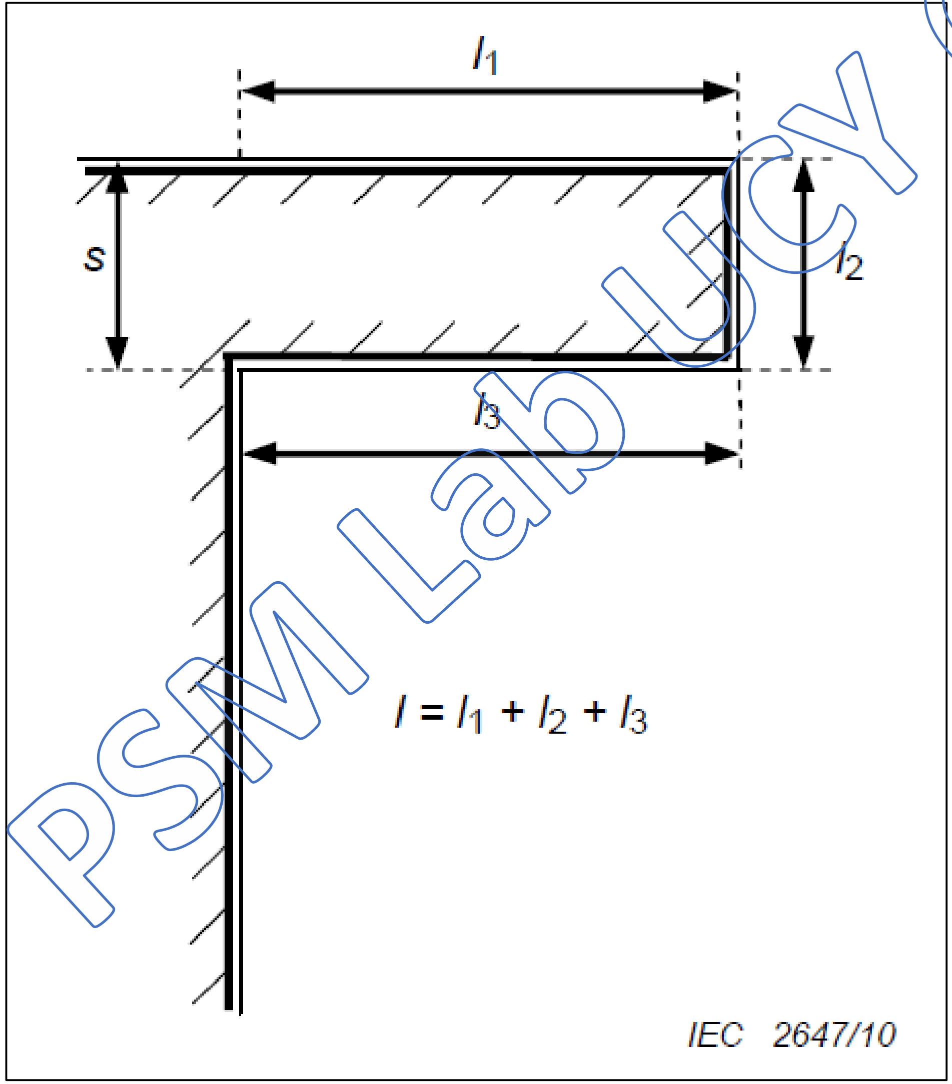
CYPRUS STANDARD

CYS EN 62305-3:2011

Protection against lightning - Part 3: Physical damage to structures and life hazard

Case study: EN 62305-3

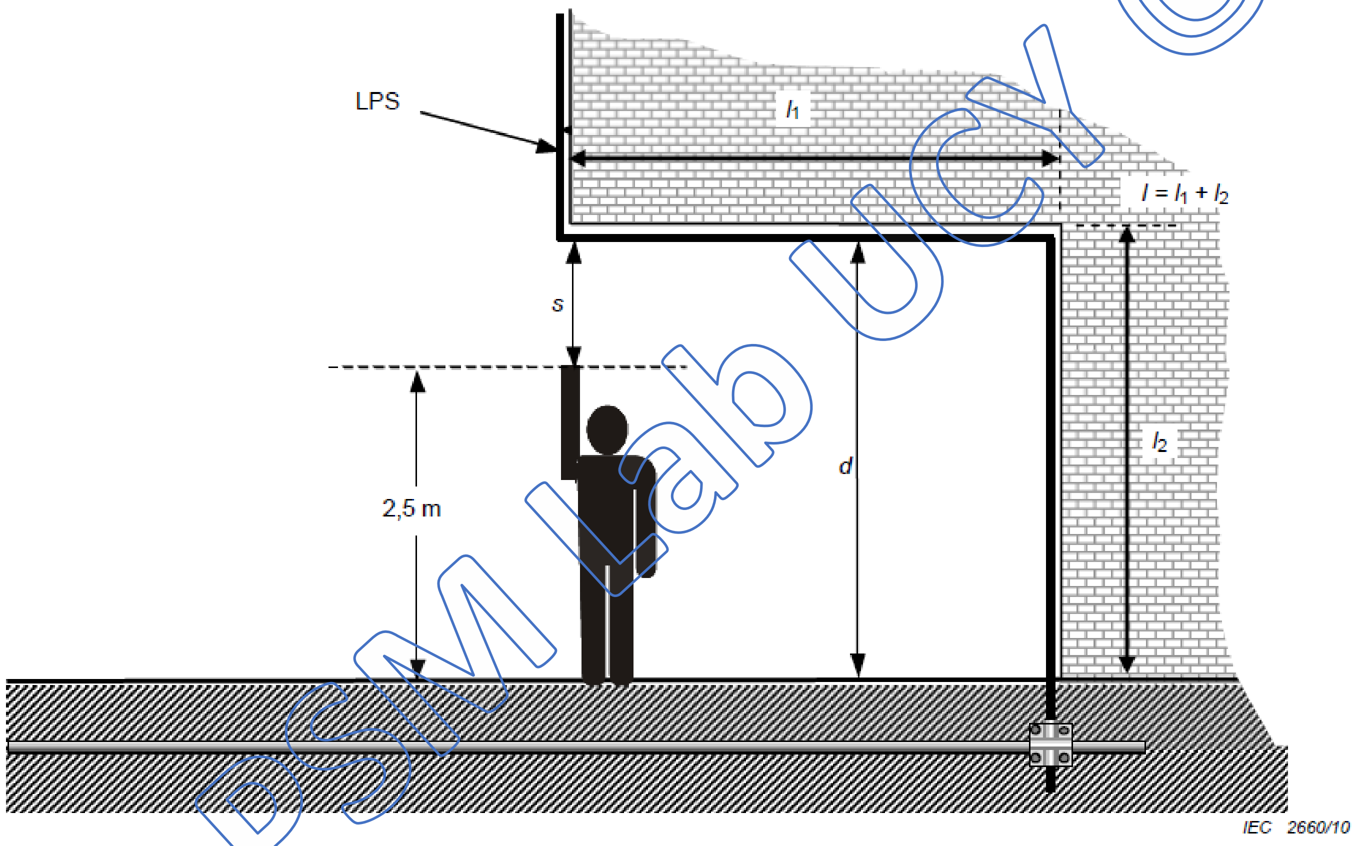
- Down-conductors are the continuation of the Air-termination System. The formation of loops shall be avoided, but where this is not possible, the distance s, measured across the gap between the two point on the conductor and the length, l, of the conductor between those points shall conform as defined in the relevant standard.



$$s = \frac{k_i}{k_m} \times k_c \times l$$

Case study: EN 62305-3

- Down-conductors are the continuation of the Air-termination System. The route of the down-conductor to the earthing system should be evaluated with reference to the minimum permissible safety clearance to avoid dangerous interference with the human body.



Key

d	actual distance >*s*
s	separation distance according to 6.3
l	length for the evaluation of separation distance *s*

NOTE The height of the person with raised hand is taken to be 2,5 m.

$$s = \frac{k_i}{k_m} \times k_c \times l$$

Separation safety distance – calculation

$$s = \frac{k_i}{k_m} \times k_c \times l$$

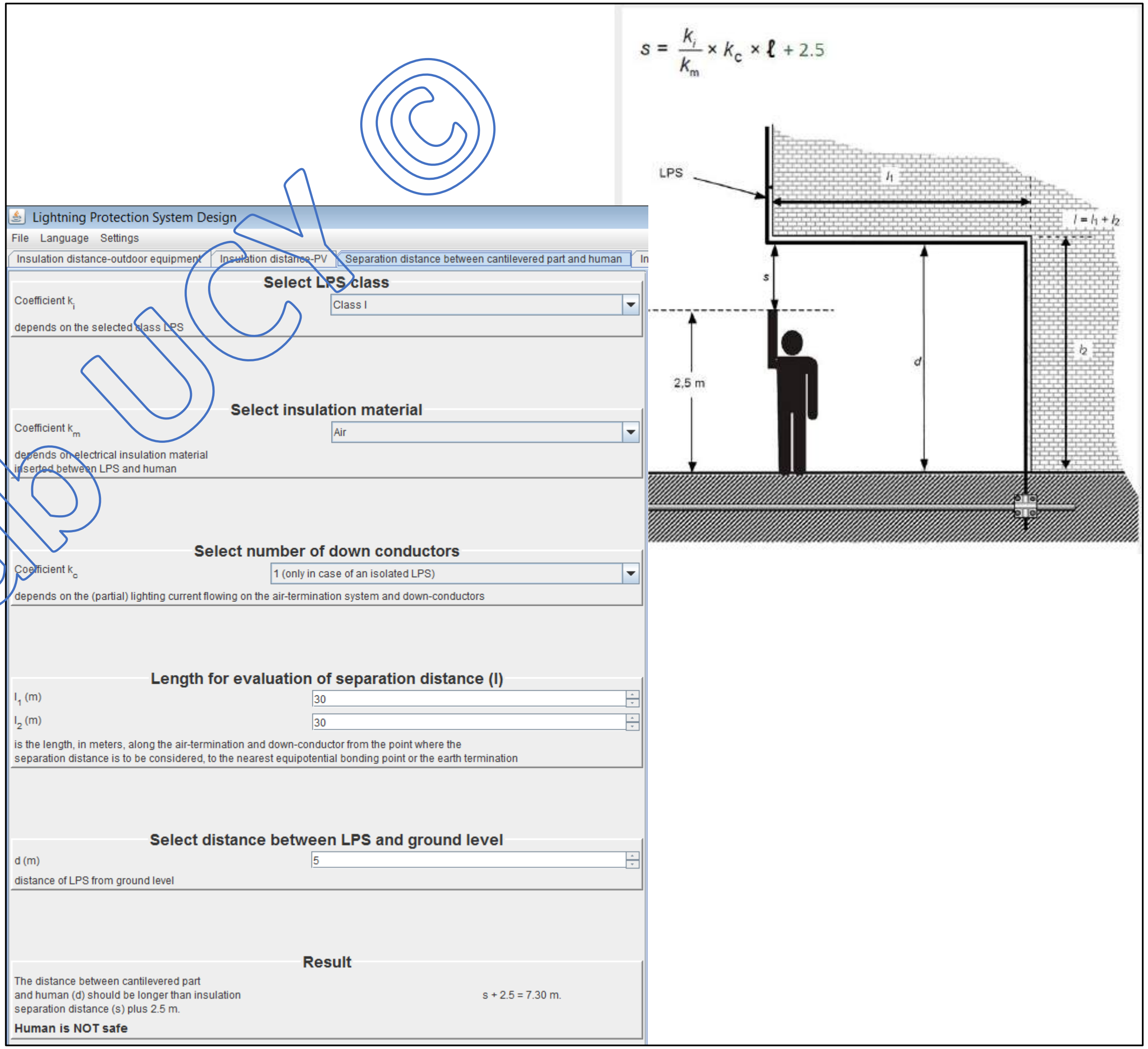
Where,	
k_i	Depends on the selected class of LPS
k_m	Depends on the electrical insulation material
k_c	Depends on the (partial) lightning current flowing on the air-termination and the down-conductors
l	Is the length, in meters, along the air-termination and the down-conductor from the point, where the separation distance is to be considered, to the nearest equipotential bonding point or the earth termination.

Down-conductors and separation distance assessment tool 62305-3

- The software has the capability to calculate:
  - The required separation distance between **down-conductors and installed equipment** (i.e. Photovoltaic system)
  - The required dimensions between **the down-conductors that form loops** (i. e. building protrusions)
  - The required dimensions **between down-conductors and a parson** (i.e. building cantilever)

- The calculations take into account:
  - LPS class
  - Number and length of down-conductors
  - Electrical insulation materials

- The results are presented in the form of:
  - Useful messages, including alternative solutions in the case where the required separation distances are not met.



Brief Operation Exhibition