



Milan Vidmar Electric Power Research Institute, Ljubljana



SKAT User Guide



Ljubljana, 2024

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Production: **Milan Vidmar Electric Power Research Institute,**
Hajdrihova 2, Ljubljana

Authors: Ana Štrukelj, M.Sc. in Mechanical Engineering
Goran Milev, B.Sc. in Electrical Engineering

Print: **Milan Vidmar Electric Power Research Institute**

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1 About the web application SKAT

The SKAT web application is designed to access and manage lightning risk at specific locations. It features an interactive map where users can select a location to determine its lightning density, which is essential for performing accurate risk calculation. The application facilitates the identification of necessary lightning protection measures in accordance with the EN 62305-2:2012 standard.

2 Environmental requirements

Supported web browsers include:

- Mozilla Firefox,
- Internet Explorer,
- Microsoft Edge,
- Google Chrome.

3 Using the SKAT Web Application

3.1 Logging into the SKAT Web Application

To access the SKAT web application, enter the address <http://www.scalar.si/skat/login> into your browser or access it through the home page of the SCALAR system www.scalar.si. On the website, select »Users Login« from the top right menu.

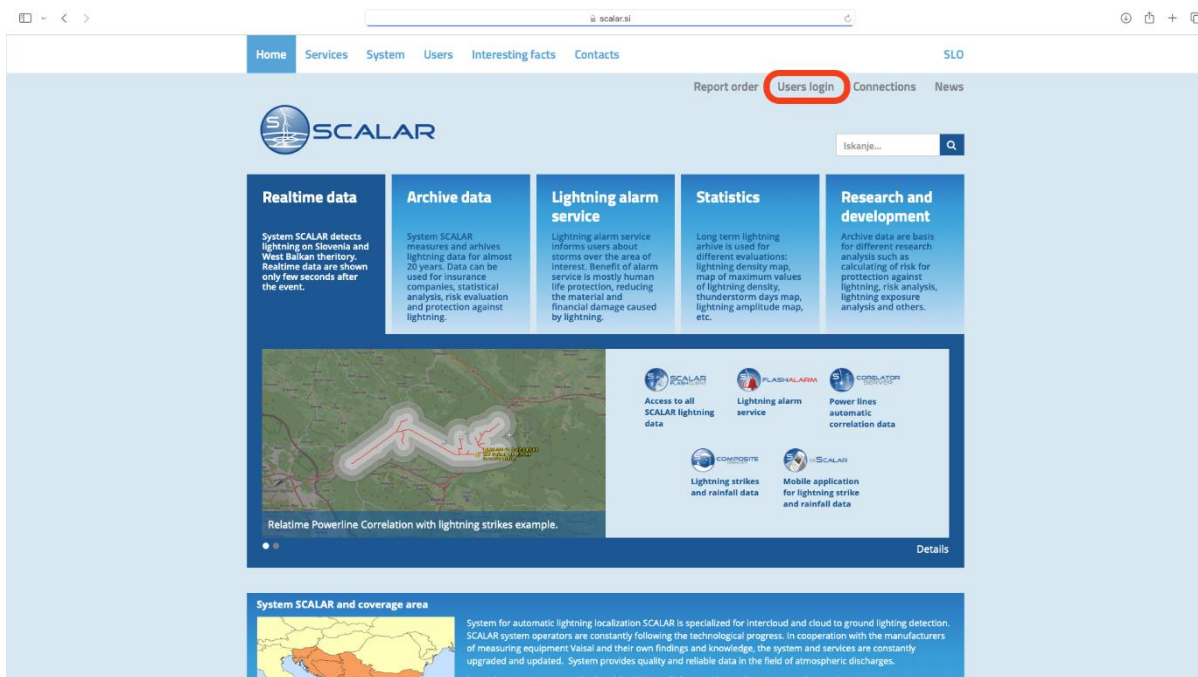


Figure 3.1: Home Page of the SCALAR System

On the left side, choose the option »SKAT Web Application Log In«. The website will then offer us the option to log in to the application or download the User Manual.

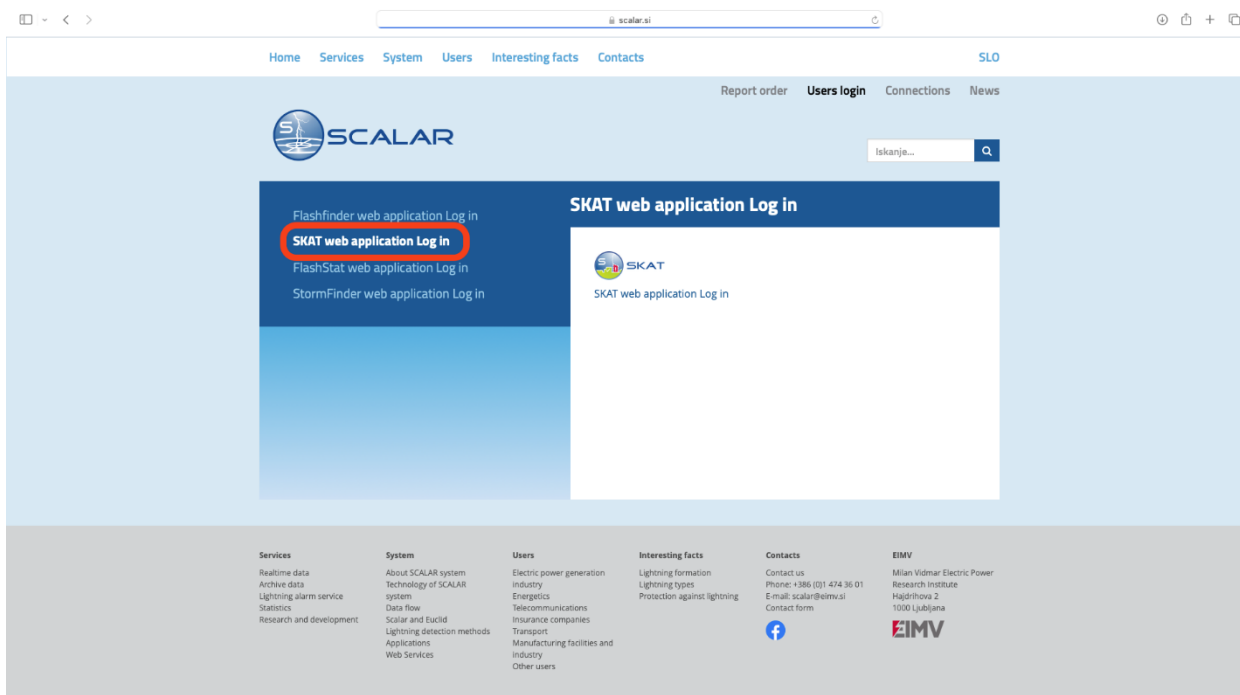
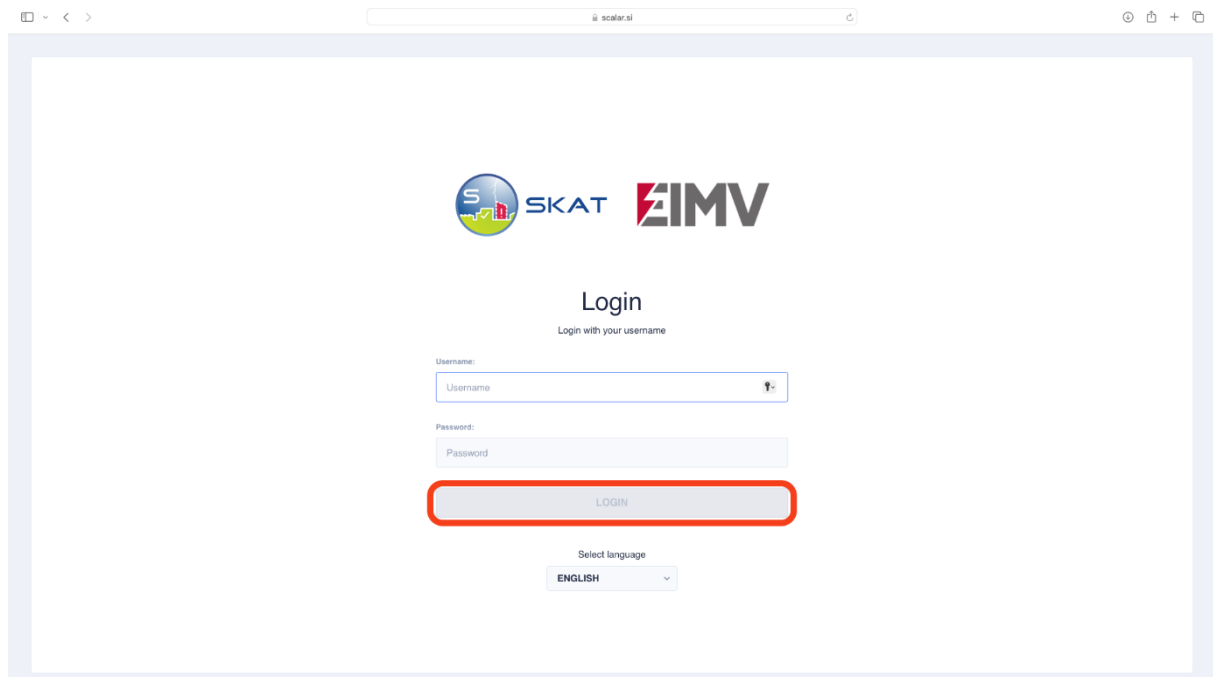


Figure 3.2: Subscriber Login Web Page

To log in, we need a valid username and password, provided by the application administrator according to prior agreement. After entering the username and password, click the »Login« button.



The screenshot shows a web browser window with the address bar displaying 'a scalar.si'. The main content area has a light blue border. At the top center, there are two logos: 'SKAT' (a blue circle with a white 'S' and a green bar) and 'EIMV' (a red and white logo). Below the logos, the word 'Login' is centered, followed by the text 'Login with your username'. There are two input fields: 'Username' and 'Password'. A red rectangular box highlights the 'LOGIN' button. At the bottom, there is a 'Select language' dropdown menu with 'ENGLISH' selected.

Figure 3.3: Logging into the SKAT Web Application

3.2 Selecting a Location and Providing Lightning Density Data for the Selected Location

Once logged into the application, you have the option to either add a new location or upload a project. Simply click the corresponding button based on your preference: »Adding New Location« or »Load Project«.

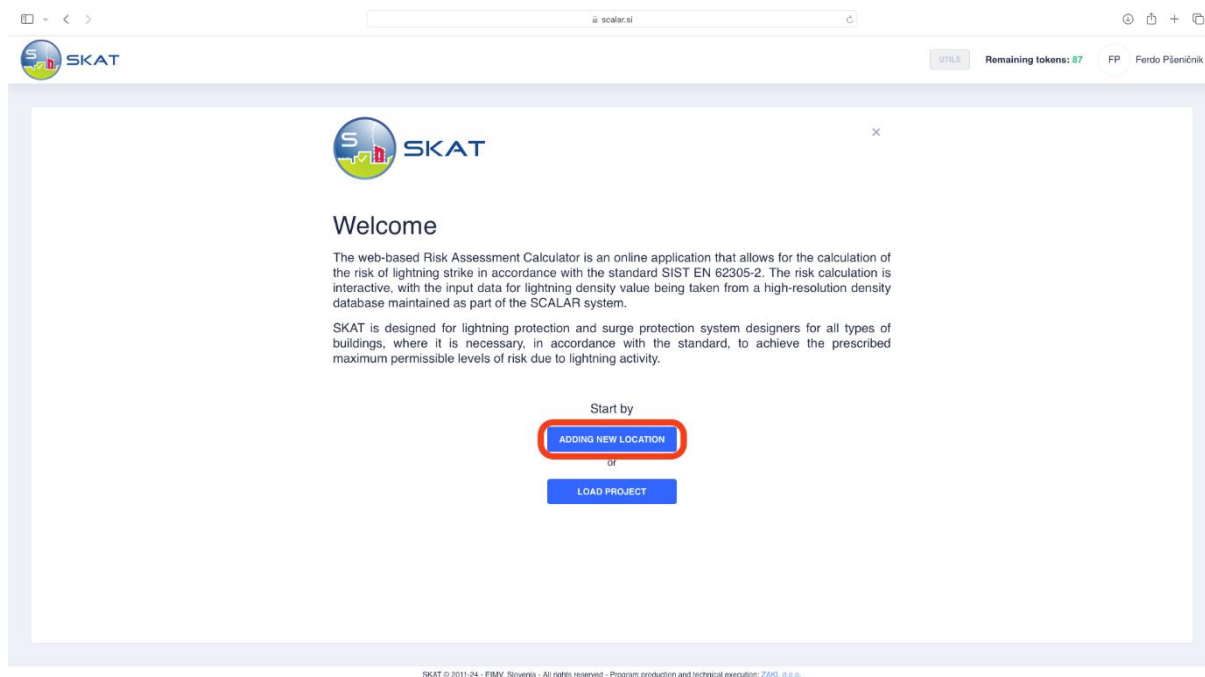


Figure 3.4: Home Page

If you're looking to find a new location, click on the »Adding new location«, which opens a new window. Here, you can enter the necessary information about the desired location, such as the street address or GPS coordinates (WGS 84). After entering the details, the location will appear on the map below. Take a moment to verify if it's the correct location. Once confirmed, click »Buy Location for 1 Token« to proceed. This action deducts one SKAT token from your account balance.

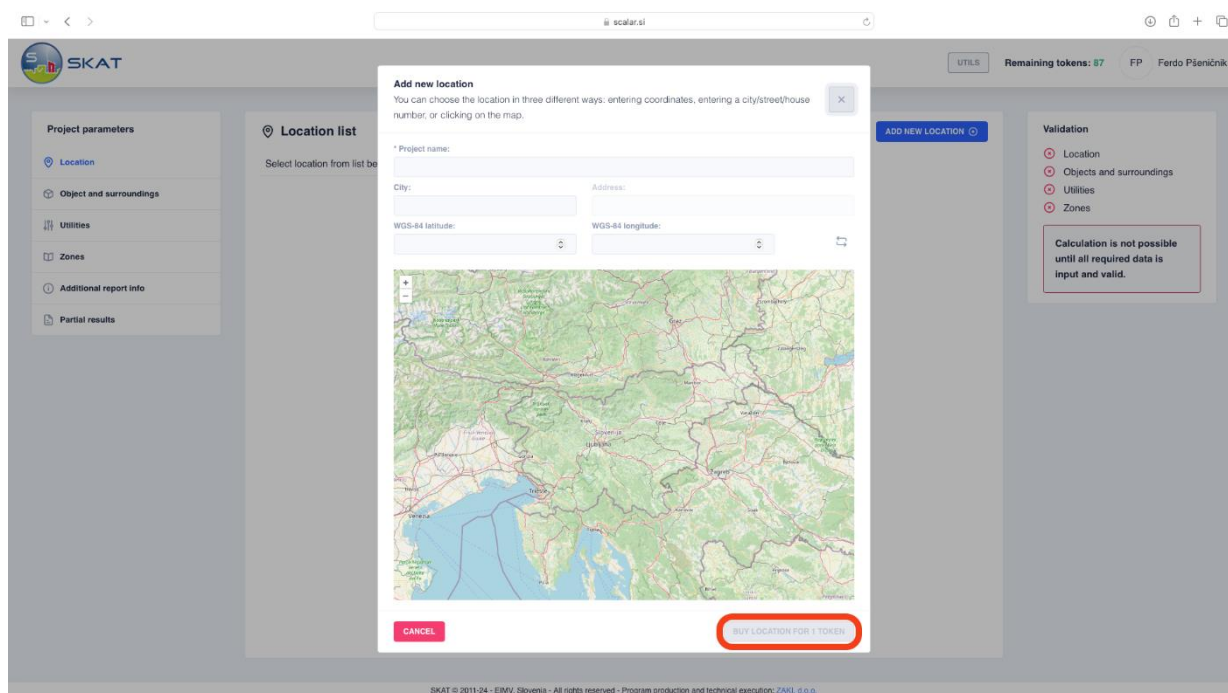


Figure 3.5: Location Selection

If you wish to upload an existing project, select **»Load Project«** from the initial window (see Image 3.4). This will open a window where you can choose the project file in JSON format. After selecting the file, click the **»Upload«** button.

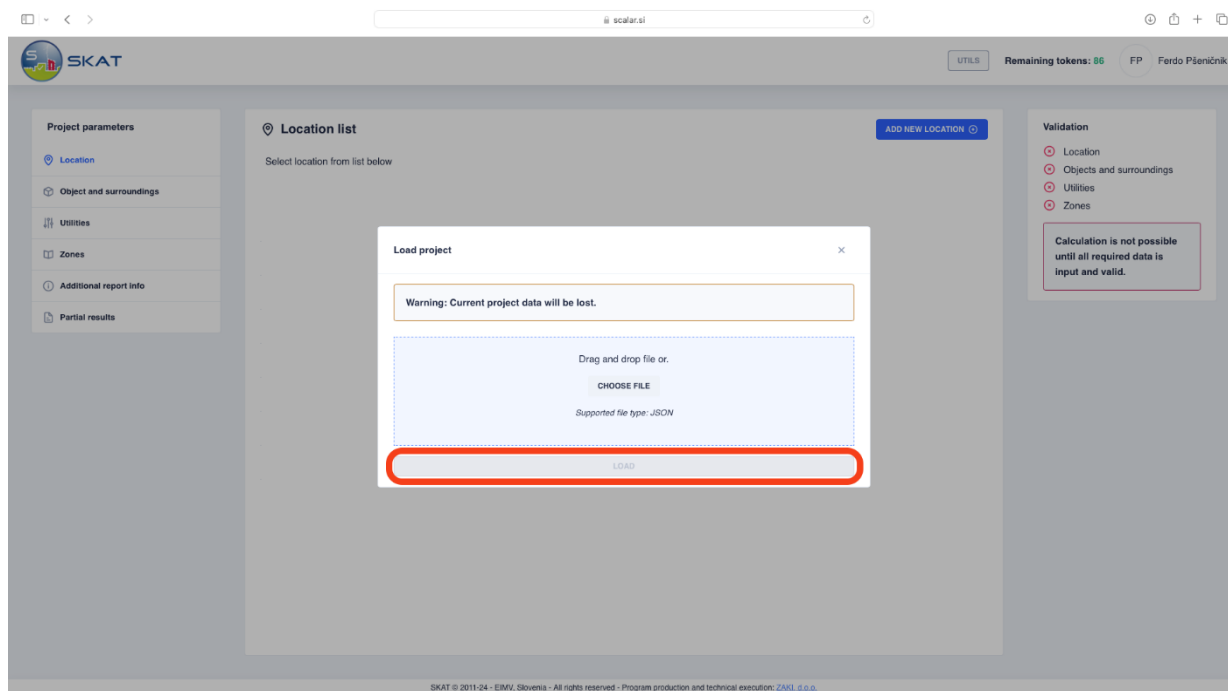


Figure 3.6: Upload Existing Project

The chosen location will appear in the **»Location List«** in both cases, allowing you to click the **»Generate Location Report«** button. The report will be automatically generated in PDF format, containing lightning density data for the selected location. For risk calculation, select **»Object and Environment«** from the left menu and refer to Section 3.4.

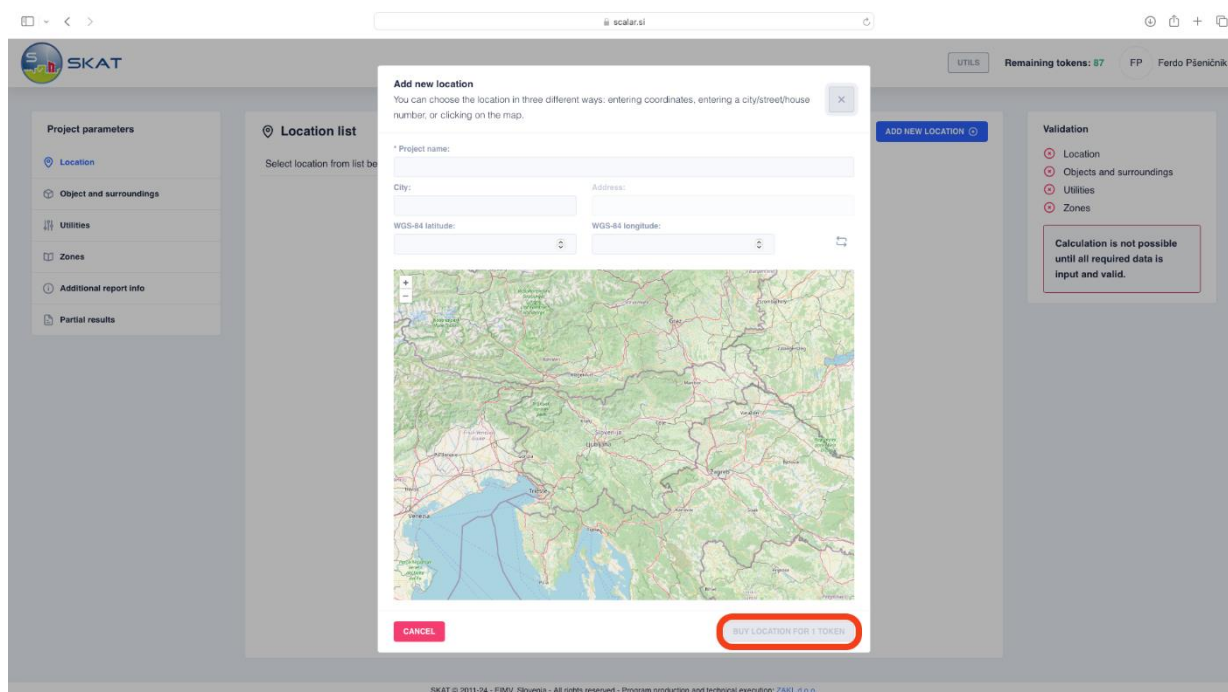


Figure 3.7: Location Confirmation and Report Generation

3.3 Saving and Resuming a Saved Project

If you haven't been able to finish a project, the program allows you to save it and continue later without the need for an additional SKAT token.

To save a project, select the »Utils« button in the toolbar, and then click »Save Project«.

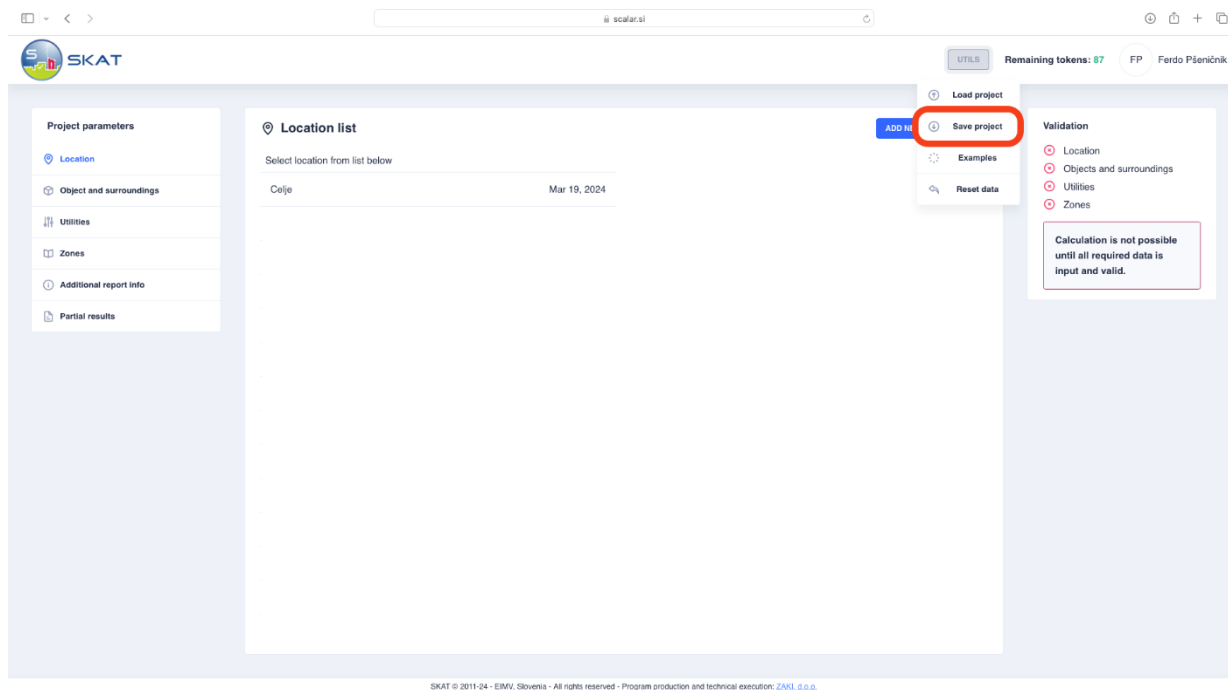


Figure 3.8: Saving the Initial Project

To resume a saved project, select »Utils« again, and then »Load Project«. Choose the appropriate project file (Supported file format: JSON) and click »Load«.

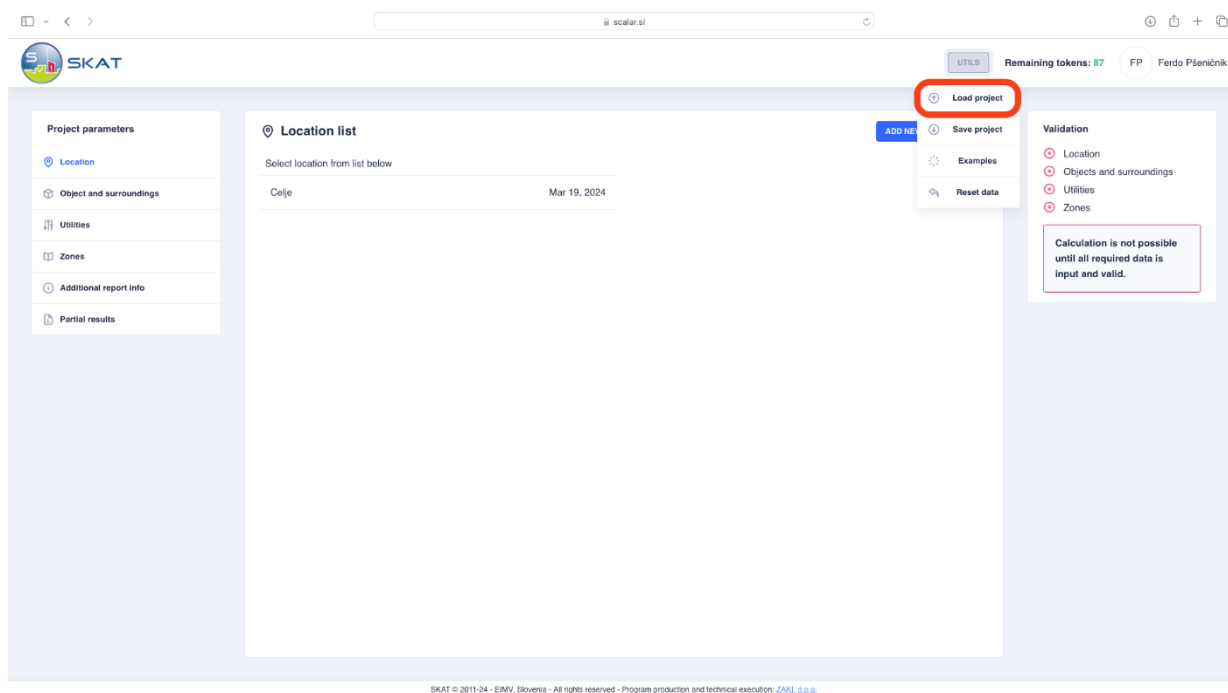


Figure 3.9: Selection and Resumption of a Saved Project

3.4 Calculating Risk for the Chosen Location

Before delving into risk assessment for a selected location, it's crucial to input specific parameters defining the object in question.

Within the »Project Parameters« menu on the left, navigate to »Object and Surroundings« and provide essential details about the object and its surroundings. Ensure that key fields such as »Length«, »Width«, and »Height of the Object« are accurately filled. For complex-shaped objects, input the total area in the designated field.

The screenshot displays the SKAT software interface. On the left, a sidebar menu under 'Project parameters' has 'Object and surroundings' selected and highlighted with a red box. The main workspace is titled 'Object and surroundings' and contains several input sections: 'Object dimensions' with fields for Length (L), Width (W), Height (H), and Collection area (A₀) [m²]; 'Other object attributes' with a dropdown for Screening effectiveness of the structure (K₀₁); 'Protective measures' with a dropdown for Class LPS (P₀); and 'Environment impact' with fields for Location (EIMV - LJUBLJANA HAJDRIHOVA ULICA 2), Lightning ground flash density (N₀): 1.020 flash/km²/year, and Location factor (C₀). A validation panel on the right indicates that calculation is not possible until all required data is input and valid. The bottom of the interface shows a copyright notice: SKAT © 2011-24 - EIMV, Slovenia - All rights reserved - Program production and technical execution: ZAG 2.0.0.

Figure 3.10: Selection of Object and Surroundings

Next, considering the magnetic shielding at the building's perimeters, select the appropriate object type from the available options:

- 1: Standard structure (e.g., house, commercial building)
- 0.0001: Specialized structure with robust magnetic shielding (e.g., antenna tower)
- Other value

In case the magnetic shielding field remains unselected, prompting manual input, be sure to provide the necessary data. If the induction loop runs closer to the shield than the prescribed safety distance, adjust the K_{S1} value accordingly. For distances within the range of $0.1 w_m$ to $0.2 w_m$, double the K_{S1} value, where w_m represents the width of the shield grid.

Proceed to select the »LPS Class«, indicating the protection level of the object:

- 1: Building lacks LPS protection
- 0.2: Building secured with LPS Class IV protection
- 0.1: Building secured with LPS Class III protection
- 0.05: Building secured with LPS Class II protection
- 0.02: Building secured with LPS Class I protection
- 0.01: Building outfitted with a lightning protection system corresponding to level 1 protection
- 0.001: Building featuring a metal roof or lightning protection system, potentially incorporating auxiliary lightning protection systems

Additionally, determine the **»Placement Factor«** of the object:

- 0.025: Surrounded by taller structures and trees
- 0.05: Encircled by structures or trees of similar or lesser height
- 1: Standalone structure with no nearby objects
- 2: Isolated structure positioned atop a hill or mound

Once the basic parameters of the object and its surroundings are established, proceed to identify the connections within the object and specify their attributes. This can be accomplished through the **»Utilities«** menu on the left.

Figure 3.11: Selection of Utilities

First, we determine the **»Connection Name«**, then in the **»Transformer Factor«** field, we specify the type of connection. Choose from the following options:

- 1: Telecommunication line
- 1: Power supply line
- 0.2: Power supply line with a transformer with two windings

In the **»Length of Connection«** field, enter the length of the line from our object to the connection point (cabinet, transformer, ...).

Next, in the **»Conduction of Lines«** field, enter the data about the shielding of the lines. If the line is shielded, you can choose whether the line shield and equipment are connected to the same busbar for potential equalization, and in the **»Shield resistance per Cable Length«** field, enter the resistance of the shield in ohms.

In the **»Installation Factor«** field, determine whether it is an overhead or underground line. Choose from the following:

- 1: Overhead line
- 0.5: Underground line
- 0: Buried cables are entirely within the mesh grounding system

In the »Environmental Factor« field, select the environment in which our object is located. Choose from the following:

- 1: Rural
- 0.5: Suburban
- 0.1: Urban
- 0.01: Urban with tall buildings

Finally, specify the »Sustainable Voltage of the Internal System«, »Dimensions of the Adjacent Building«, and »Placement Factor of the Adjacent Building«.

The number of object connections can be increased or decreased by clicking the »Duplicate« or »Add« button. For each connection, specific parameters and characteristics described above must be determined individually.

Each object can be assigned different zones, as each zone has specific parameters or protection levels, depending on the zone's importance (for example, an archive has a higher protection level than lobby or staircase). Therefore, in the »Zones« tab, we specify the number of zones contained in our object – this means the number of parts of the building with different protection levels, number of connections, or other parameters. The number of zone scan be easily increased by clicking the »Duplicate« or »Add« button. For each zone, specific parameters characteristic of that zone must be entered.

Figure 3.12: Selection of Zones

Each zone is named arbitrarily by entering the zone name in the »Zone Name« field. It is important to correctly select the »Type of Soil or Ground« on which this zone is located, as the conductivity in the event of a lightning strike depends on it. We choose from the following options:

- 0.01: Agricultural land, concrete
- 0.001: Marble, ceramic
- 0.0001: Sand, fabric, carpet
- 0.00001: Asphalt, linoleum, wood

Then, we determine the **»Protective Measures for Touch and Step Voltage«** in our zone. We choose from the following options:

- 1: No protection
- 0.1: Warning signs
- 0.01: Electrical isolation of exposed conductive parts
- 0.01: Proper potential equalization parts
- 0: Physical restrictions

Considering the activity conducted within the zone, we also determine the **»Fire Risk Level in the Building Zone«**:

- 1: Explosion risk, Zones 0, 20 and hard explosive
- 0.1: Explosion risk, Zones 1, 21
- 0.001: Explosion risk, Zones 2, 22
- 0.1: High fire risk
- 0.01: Ordinary fire risk
- 0.001: Low fire risk
- 0: No fire or explosion risk

And any **»Fire Consequences Measures«**:

- 1: No measures
- 0.5: Fire extinguishers, manual fire suppression installations, manual fire alarm installations, hydrants, fire walls, fire stairs
- 0.2: Automatic fire extinguishing installations, automatic fire alarm systems

We can also specify **»Special Hazard«**:

- 1: No special hazards
- 2: Low panic level (building with two staircases, fewer than 100 people)
- 5: Average panic level (buildings for cultural and sports events with 100 to 1000 participants)
- 5: Hindered evacuation of people (e.g., hospitals)
- 10: High panic level (sports and cultural facilities with over 1000 participants)

For each zone, we also determine the **»Number of Persons in Zone«** and the **»Time that Persons Spend in the Zone«**.

To calculate the loss cost in each zone, we define **»Animal Loss Costs«**, **»Building Loss Costs«**, **»Content Loss Costs«**, **»System and Cultural Heritage Loss Costs«**.

Each type of damage can independently or in combination with other events result in consequential loss that requires insurance. The type of loss depends on the characteristics of the object and individual zones and their contents. It is essential to determine parameters for loss of human life. For **»Loss because of Physical Damage«**, we analyse the risk of loss of human life due to building damage (for example, the lives of people in a building where there is a risk of explosion due to damage that would jeopardize the building). We can choose from the following options:

- 0.1: Explosion risk
- 0.1: Hospitals, hotels, schools, public buildings
- 0.05: Theatres, churches, museums
- 0.02: Industrial and commercial buildings
- 0.01: Other buildings
- 0: No damage

Additionally, we identify **»Losses due to Damage to Internal Systems«**. Here, we assess the risk of loss of human life resulting from the failure of internal systems (for example, a patient's life in an operating room depends on the operation of devices; the failure of these device scan endangers the patient's life). We determine the following risk levels:

- 0.1: Explosion risk
- 0.01: Hospital – intensive care unit and operating room
- 0.001: Other parts of the hospital
- 0: No damage

We also define parameters for the loss of public supply. This considers **»Physical Damage Losses«** affecting public service facilities (e.g., power lines, gas pipes, water pipes, etc.). we choose from the following options:

- 0.1: Gas, water, electricity supply
- 0.01: TV, telecommunications
- 0: No damage

When determining **»Losses due to Damage to Internal Systems«**, we define losses of public supply, this time not due to damage to the facility itself, but due to the failure of internal systems on which the supply depends (for example, a malfunction of the main control computer). In this case, we can choose from the following options:

- 0.01: Gas, water, electricity supply
- 0.001: TV, telecommunications
- 0: No damage

We can also record losses of cultural heritage, especially due to physical damage, as building damage can result in the destruction of cultural heritage (for example, artifacts in a museum can burn in a fire). Here, we can choose from the following options:

- 0.1: Museums, galleries
- 0: No damage

We must also determine the losses of economic value, again due to **»Physical Damage«**, choosing from the following options:

- 1: Explosion risk
- 0.5: Hospitals, industrial buildings, museums, agriculture
- 0.2: Hotels, schools, office buildings
- 0.1: Other buildings
- 0: No damage

Furthermore, we specify **»Losses due to Damage to Internal Systems«**, choosing from the following options:

- 0.1: Explosion risk
- 0.01: Hospitals, industrial and commercial buildings, hotels
- 0.001: Museums, agriculture, schools, churches
- 0.0001: Other buildings
- 0: No damage

Finally, we define the characteristics of connections. If we have multiple connections, we determine the characteristics of each one separately. Here, we determine the **»Type of Internal Wiring«**:

- 1: Unshielded cable – no precautions to avoid loops
- 0.2: Unshielded cable – precautions to avoid large loops
- 0.01: Unshielded cable – precautions to avoid loops
- 0.0001: Shielded cables and cables running in metal conduits

Then, we determine the **»Coordinated Surge Protection SPD«** we have:

- 1: Without SPD
- 0.05: Lightning strike protection level III-IV
- 0.02: Lightning strike protection level II
- 0.01: Lightning strike protection level I
- 0.005: [NOTE 3]

We can choose multiple options for **»Protective Measures against Touch and Step Voltages in the Supply Line in the Event of a Lightning Strike«**:

- 1: No protection
- 0.1: Warning signs
- 0.01: Electrical isolation of exposed down conductors
- 0: Physical limitations

In the left menu, select the option »Additional Report Info«, where you can enter additional data such as »Project Investor«, »Object Title«, »Plan Number«, »Project Number«, and »Project Lead«. While these details are not essential for risk calculation, they serve as additional information in the report.

Project parameters

- Location
- Object and surroundings
- Utilities
- Zones
- Additional report info**
- Partial results

Additional report information *

Project Investor

Object title

Plan number

Project number

Project lead

* This data is not necessary for risk calculation but only for the report output

Results

Loss of life (L1):

$R1 \leq R1_T$

$R1: 2.644 \times 10^{-6}$

$R1_T: 1 \times 10^{-5}$

Loss of service (L2):

$R2 \leq R2_T$

$R2: 0$

$R2_T: 0.001$

Cultural heritage loss (L3):

$R3 \leq R3_T$

$R3: 0$

$R3_T: 1 \times 10^{-4}$

Economic value loss (L4):

$R4 \leq R4_T$

$R4: 0$

$R4_T: 0.001$

GENERATE RISK REPORT

Figure 3.13: Selecting additional information

Once all the necessary parameters for calculating the risk of our object are determined, select the option »Partial Results« from the left menu. Here, you can view the calculated risk factors for loss of human life, public supply, cultural heritage, and economic loss.

Project parameters

- Location
- Object and surroundings
- Utilities
- Zones
- Additional report info
- Partial results**

Partial results

RISK DANGEROUS EVENTS COLLECTION AREAS

R1	Z1	SUM
R1A	2.644×10^{-6}	2.644×10^{-6}
R1B	0	0
R1C	0	0
R1M	0	0
R1U	0	0
R1V	0	0
R1W	0	0
R1Z	0	0
SUM	2.644×10^{-6}	2.644×10^{-6}

R2	Z1	SUM
R2A	0	0
R2B	0	0
R2C	0	0
R2M	0	0
R2U	0	0

Results

Loss of life (L1):

$R1 \leq R1_T$

$R1: 2.644 \times 10^{-6}$

$R1_T: 1 \times 10^{-5}$

Loss of service (L2):

$R2 \leq R2_T$

$R2: 0$

$R2_T: 0.001$

Cultural heritage loss (L3):

$R3 \leq R3_T$

$R3: 0$

$R3_T: 1 \times 10^{-4}$

Economic value loss (L4):

$R4 \leq R4_T$

$R4: 0$

$R4_T: 0.001$

GENERATE RISK REPORT

Figure 3.14: Display of partial results

If all the factors in the right display window are highlighted in green, it indicates that our object is well-protected and that the risk factors for individual losses are within prescribed limits. If any of the factors are marked in red, it indicates that certain parameters of the object, connections, and zones, while continually checking the calculation of intermediate results. When all the factors are highlighted in green, based on the modified parameters, we have found a solution where all risk factors are within prescribed limits. If we are satisfied with the results of the risk factors, the program automatically generates a report with all the solutions and intermediate results with a single click on the **»Generate Risk Report«** button, which begins to download automatically and can be found in the downloads folder.

To simplify the calculation, you can click on the **»Utils«** button in the toolbar and select the **»Examples«** option. Here, you will find predefined types of buildings such as rural house, office building, hospital, or residential complex. The program will automatically load preset values for the selected type of object, as defined by the standard. Select the desired test case and confirm it by clicking the **»Load«** button.

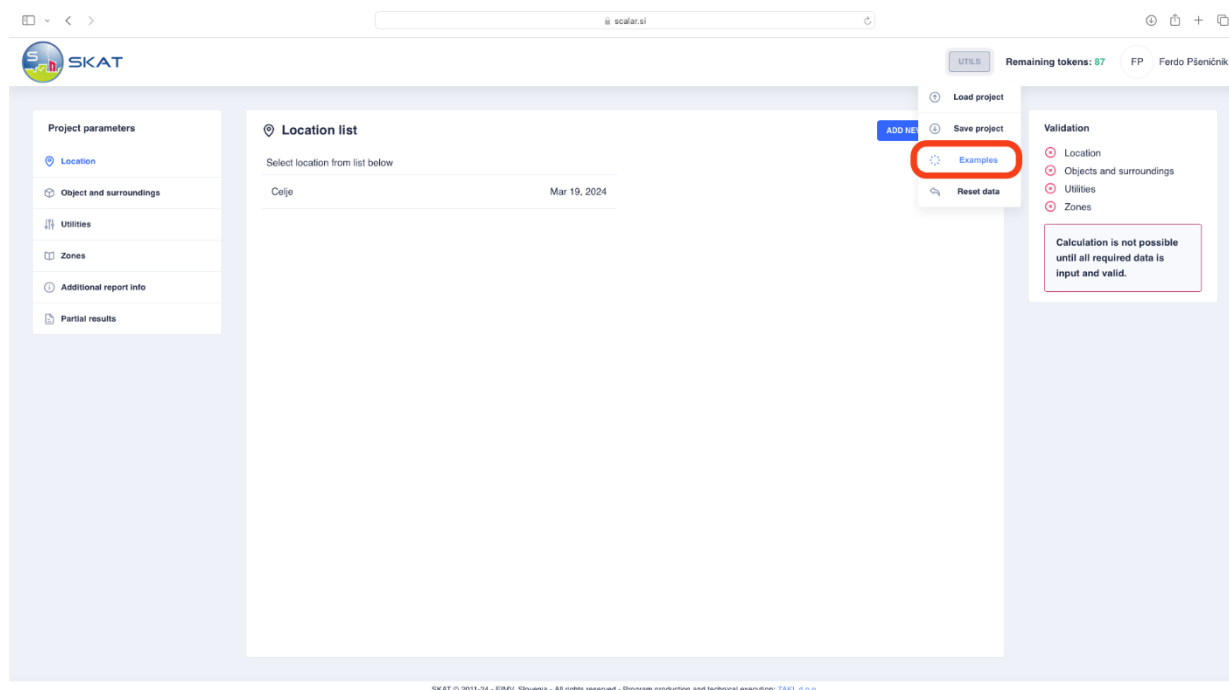


Figure 3.15: Loading Examples

3.5 Selecting a New Location, Help, and Logging Out of the System

To conclude the current project and perform a risk assessment for another location, select the **»Location«** option in the left menu and click the **»Add Location«** button. This opens a new window for selecting the location (see Chapter 3.2). When choosing a new location, one SKAT token will be deducted. Information about the **»Number of Tokens«** can be found at the top of the window.

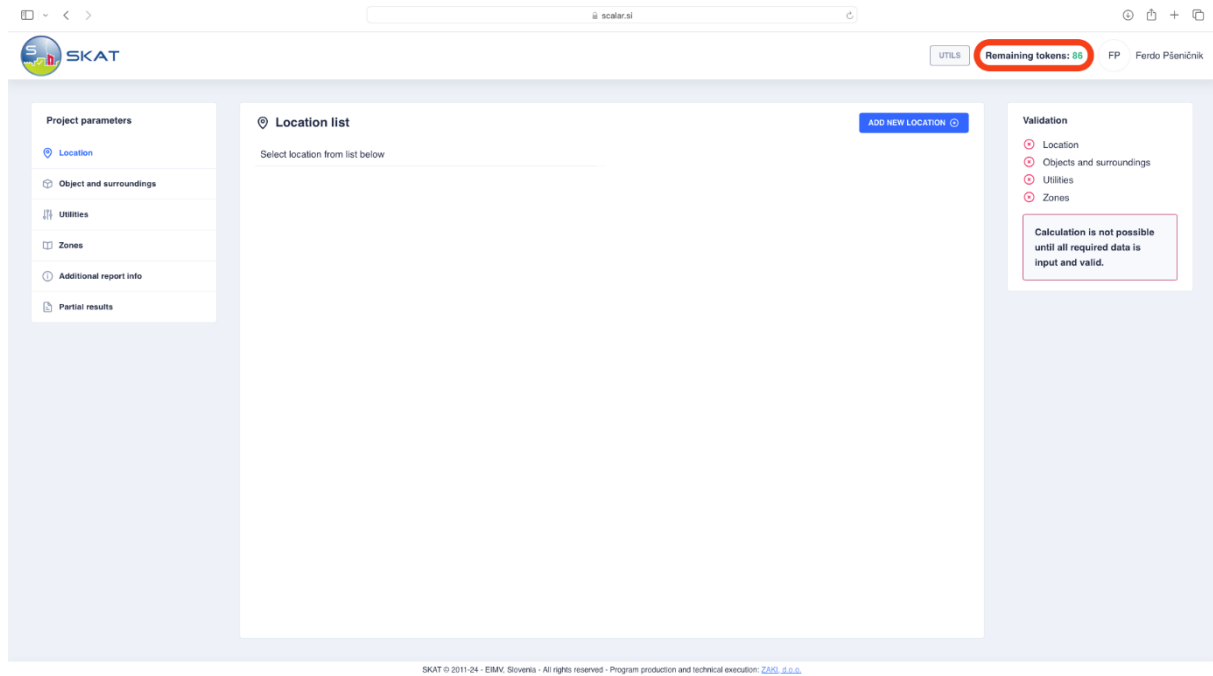


Figure 3.16: Number of Tokens Available

When finished using the application, it is important to log out correctly. This is done by clicking on your name in the top right corner and selecting the **»Log Out«** option.

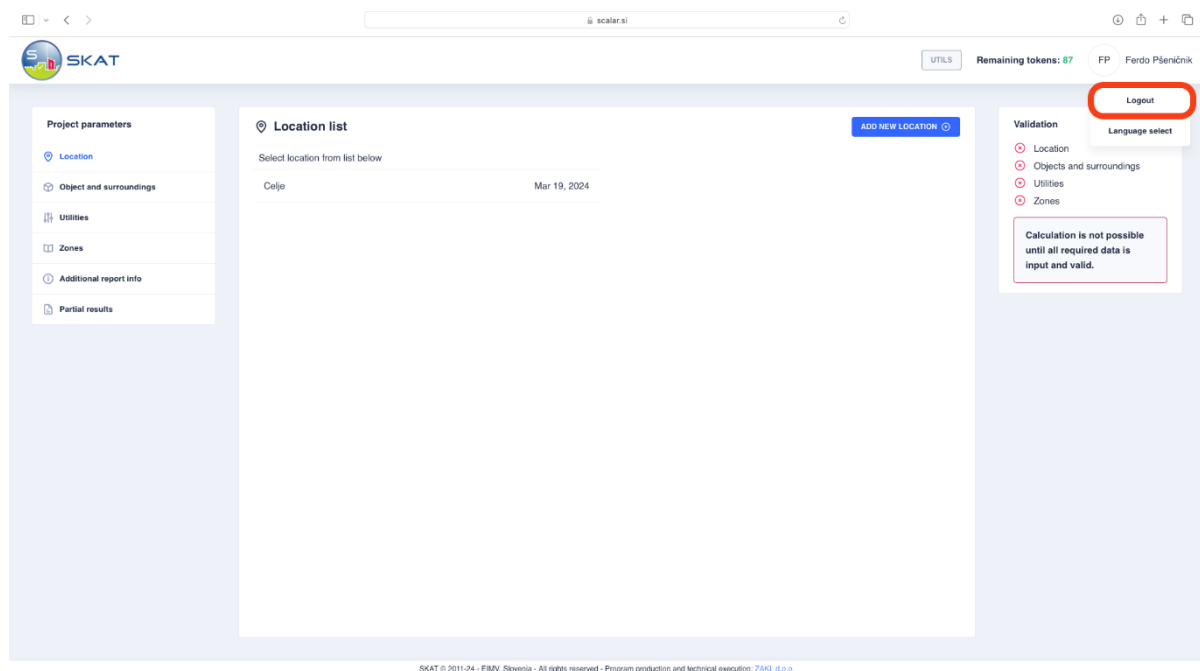


Figure 3.17: Logging Out of the System

Appendix

4.1 General information about the SCALAR System

In 1998, the SCALAR system for automatic localization of atmospheric discharges was established in Slovenia. It collects data on lightning strikes between clouds and the ground in a wider area of Slovenia.



Figure 4.1: Locations of SCALAR System Sensors

A recorded lightning strike has several parameters. The numerical data defining it include:

- timestamp of the strike,
- geographical latitude and longitude of the location,
- current amplitude in ka,
- number of return strokes, and
- quality parameters.

The main parameters indicating the system's quality are accuracy and detection efficiency. Analyses show that the SCALAR system provides location accuracy within 150 m, while the detection efficiency exceeds 98% for lightning with a current over 5 kA.

For more information about the SCALAR system, visit the website: <http://www.scalar.si>

3.2 Lightning Density Map

The density of lightning strikes serves as the primary indicator of the extent of exposure to atmospheric discharges. Lightning density reflects the average number of atmospheric discharges over an extended period within a specific geographical area, expressed as the number of strikes per square kilometre per [strikes/km²/year].

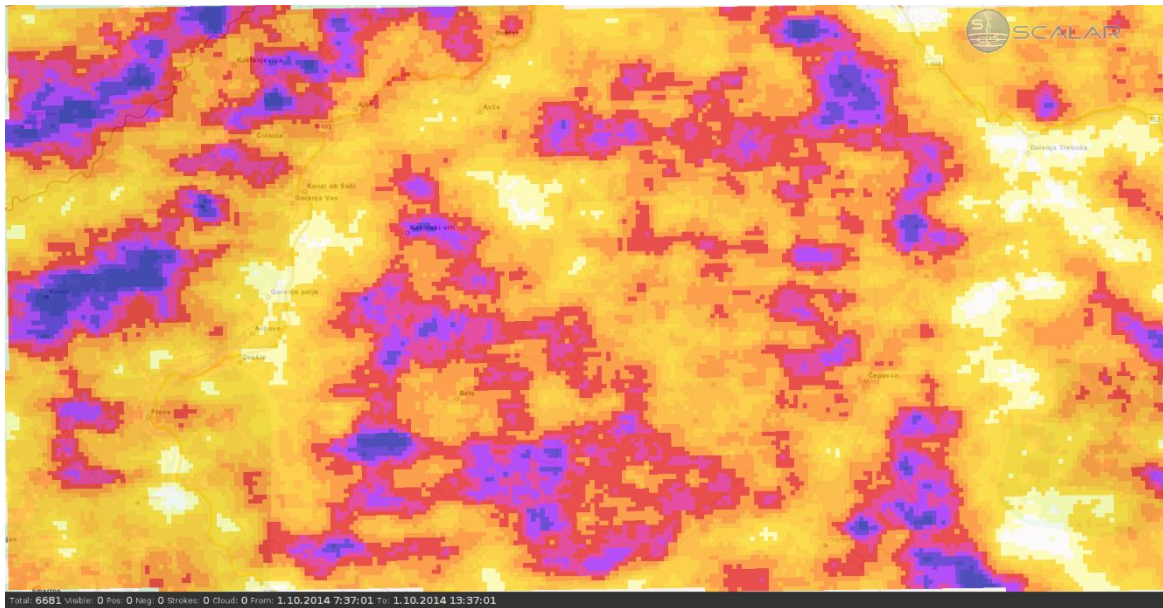


Figure 4.2: Lightning Density Map

3.3 Calculation of Lightning Density Using the Error Ellipse Method

While the location of a lightning strike typically constitutes a point event (excluding forked lightning), the SCALAR system can determine only the most probable point (coordinate) of the strike. The uncertainty surrounding this result is represented by an ellipse. This ellipse is defined by major and minor axes, along with an angle of inclination. It represents the intersection of a three-dimensional Gaussian envelope, which accounts for random influences in a twisted orthogonal system subject to normal distribution. A narrower scatter angle of measurement results in each axis corresponds to smaller axes and, consequently, a reduced size of the ellipse. A smaller area encompassed by the ellipse indicates fewer uncertainty regarding the calculated location of the atmospheric discharge.

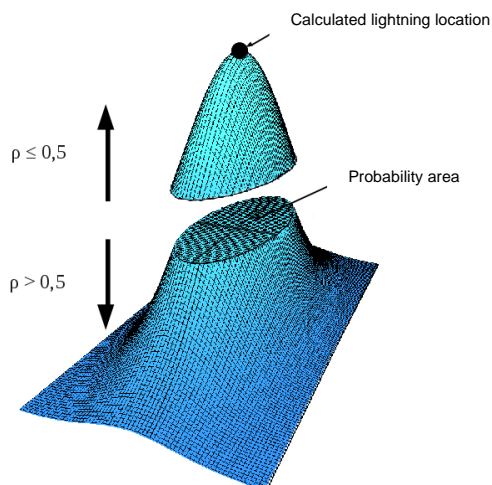


Figure 4.3: Probability Contour Map of Location

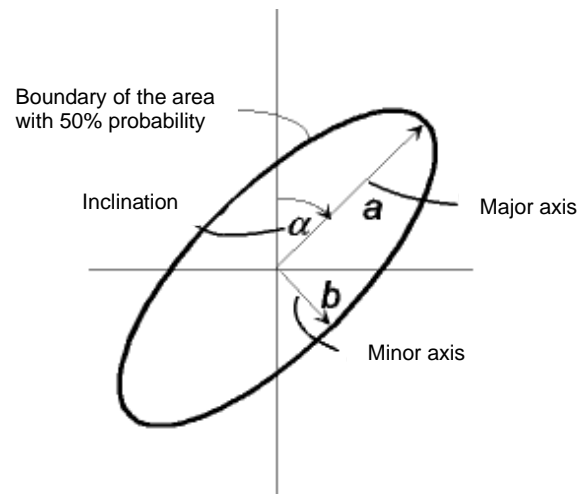


Figure 4.4: Error Ellipse with Semimajor Axis a and b and Inclination α

3.4 Formation of lightning

The onset of lightning is characterized by enduring electric field strength in air mixed with water droplets, approximately 10 kV/cm (compared to 30 kV/cm in dry air). Once the electric field surpasses this critical threshold, air ionization occurs. Given that the electric field within a cloud is typically stronger than at ground level, lightning initiation begins within the air. Under specific atmospheric conditions, a phenomenon known as a leader form from a streamer, rapidly extending from the lower portion of the cloud – typically abundant in negative charge – toward the ground. This leader ionizes the air along its path, establishing negatively charged channels. The leader's step length typically ranges between 5 and 50 meters. Its travel speed varies and is notably slower than that of light, usually around 0.1% of the speed of light. An electric current flow through the leader channel, with a relatively low intensity, approximately 20 mA, due to the channel's significant resistance, about 1,45 MΩ. At this juncture, multiple leaders often emerge, collectively forming a branched channel structure alongside the primary leader. The process of lightning genesis is visually depicted in Figure 4.5.

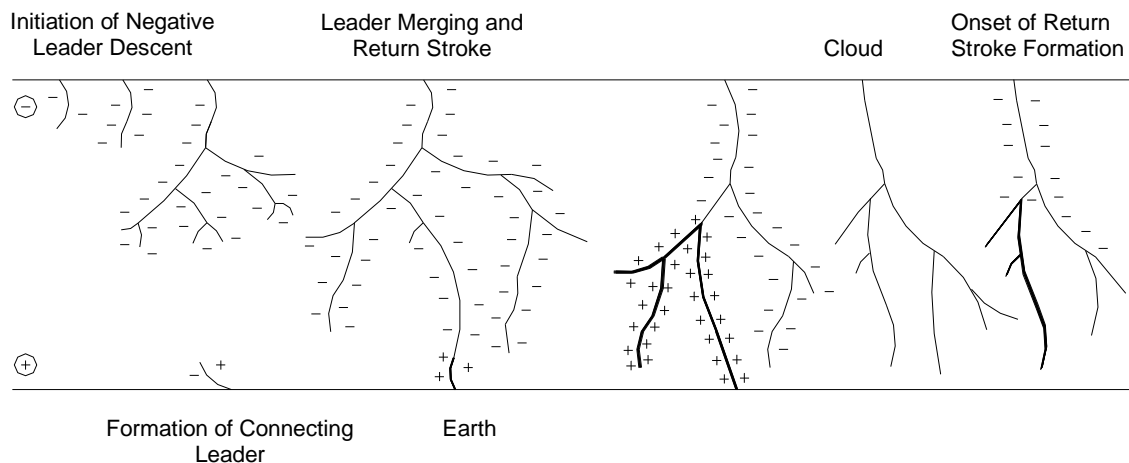


Figure 4.5: Sequence of Lightning Formation (Leader Propagation and Return Stroke)

As the leader approaches ground level, a connecting leader begins to form, expanding in the opposite direction. When the primary leader contacts one of the connecting leaders at their convergence point, a return stroke ensues. The current within the channel then rapidly escalates to values ranging from 1 to 200 kA, elevating the channel's temperature to several thousand Kelvin. The resulting heated air, expanding rapidly, generates a sonic wave, perceived as thunder.

The voltage drops within the channel averages approximately 60 V/cm. The propagation speed of the return stroke closely approximates 1/10 of speed of light. The duration of the substantial current ranges between 200 to 500 μs, followed by a decrease to a lower level (e.g. 1 kA), which gradually diminishes over time (ms). During this phase, currents from other segments of the charged cloud redirect towards the central discharge region. Simultaneously, in the cloud region where the lightning originated, charge exchanges intensify potential differences relative to other areas with excess negative charge. This may lead to multiple discharges between adjacent regions within the cloud and the discharged primary region. Consequently, a new leader forms, initially encountering the still hot and ionized air within the channel in route to the ground. The speed of this subsequent leader significantly exceeds that of the initial leader. Upon reaching the ground (this time without a connecting leader), a return stroke (re-strike) is triggered. This sequence of events may repeat several times. Each subsequent strike exhibits a more uniform shape than the initial strike. The duration of the initial phase typically falls within the range of 0,5 to 1 μs, with the decline in current following an exponential trend. Observational data indicate that the initial strike's current is generally the highest, although in certain instances, the maximum current may occur during the second strike or later.

3.5 Types of Lightning

Lightning manifests in various forms, each categorized based on different criteria. Firstly, it is classified by its location: intra-cloud, cloud-to-cloud, and cloud-to-ground lightning. Cloud-to-ground lightning is further subdivided into positive and negative strikes. Negative strikes, which discharge negative charge from the cloud, represent approximately 90% of all cloud-to-ground lightning occurrences. Additionally, cloud-to-ground lightning can be differentiated by whether it is upward or downward strokes.

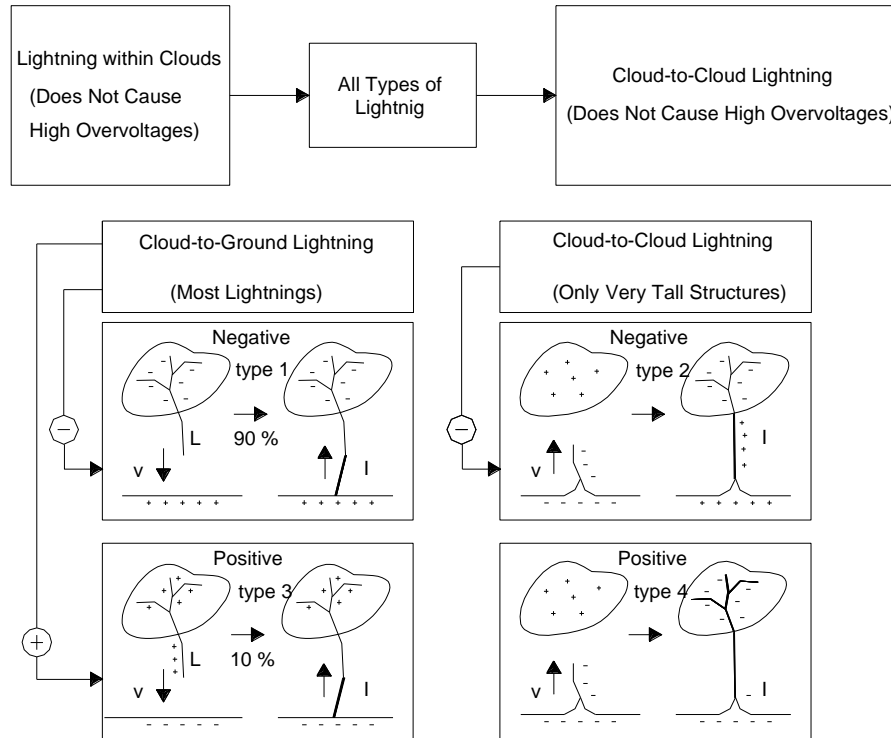


Figure 4.6: Different Types of Lightning

A notable characteristic of lightning is its profound unpredictability. Forecasting its occurrence at a precise micro-location remains exceedingly challenging. All assessments can only offer a probability of lightning in each area.