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Assessment of Lightning Protection System in University Campus

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Abstract – Lightning is a natural phenomenon that typically results in significant physical damage in areas where it strikes. Extensive research has been conducted to mitigate the effects of this damage, leading to the identification of specific precautions and practices. By adhering to both Turkish and international standards, an optimal lightning protection system can be established by integrating various components. The lightning protection system comprises an internal lightning (lightning rod) installed within the building, an external lightning system chosen based on the building's structure, and a robust grounding system. These components must adhere to established standards and techniques to ensure their effectiveness. In this paper, the protection of structures from lightning, analysis of the existing systems, the determination of the problems and the evaluation of the solution proposals have been carried out in order to reduce the loss of life, property and service that may ocur in terms of Occupational Health and Safety in and around the Balkan Campus of Trakya University. By making the width-length-height measurements of the buildings located in the campus, the lightning risk calculations of the buildings, the lightning protection radius calculations of the existing protection systems and the determination of the grounding resistances have been made. As a result, it was determined that 17 of the 29 detected lightning rods were inappropriate and maintenance-repair-replacement activities should be carried out immediately. Additionally, it has been calculated that the lightning protection radius is insufficient.

Keywords – Lightning, Lightning Protection Systems, External Lightning, Lightning Rod, Grounding Systems

I. Introduction

Lightning is a high-voltage electrical discharge that restores the electrostatic balance in the environment. Think of lightning as a way to equalize a large-scale buildup of static electric charge. Similar to static electricity, lightning results from the interaction between oppositely charged objects striving to achieve equilibrium [1]. Lightning discharge occurs in the form of channel discharge through large electrode apertures. For lightning discharge to happen, the electric field strength in the cloud must reach approximately 30 kV/cm [2]. When the field strength inside a cloud increases sufficiently, it leads to cloud-cloud discharge, cloud-in-cloud discharge, or cloud-surface lightning. In some cases, when the electric field accesses a certain value near tall structures or sharp points, upward lightning may consist. The polarity, waveform, and peak value of the lightning current are distinctive characteristics of lightning. Lightning discharges can be negative or positive in polarity, with the majority, ranging from 70% to 90%, being negatively charged [3-5].

Numerous studies on lightning have been conducted to date, but certain key studies stand out in the development of this literature. In 1908, Wagner conducted the initial theoretical analysis into induced lightning surges in power transmission lines, theorizing the causes of lightning strikes on these lines [6]. In 1929, Bewley substantiated Wagner's theory by demonstrating that the induced electric field caused by lightning doesn't dissipate instantaneously [7]. In 1942, C.F. Wagner and Mc.Cann, in their study on induced overvoltages, highlighted the significance of ambient temperature in thunder formation [8].

In a 1948 paper, Szpor calculated induced voltages resulting from vertical lightning strikes using more complex assumptions than Wagner and Mc.Cann, emphasizing the need to consider both magnetic effects and electrostatic induction. These findings were deemed applicable primarily to regions near the point of lightning strike [9]. In 1954, Golde conducted a study on the impact of induced voltages on the failure frequency of transmission lines, employing assumptions slightly different from those of Wagner and Mc.Cann. However, Golde found that the difference between various hypotheses and peak value of imposed voltages was minimal. Golde's calculations, performed analytically, were based solely on scalar potential [10]. In 1955, R. Lundholm calculated induced voltages on both short and long-range high-voltage (HV) transmission lines by approximating Wagner and Mc.Cann's assumptions. In this derivation, he omitted consideration of the magnetic field, which was later found to be unsatisfactory from a theoretical perspective [11]. In 1958, Rusk calculated induced voltages for low-voltage (LV) transmission lines with both short and long ranges, establishing a formula expression that is still widely used and forms an important international standard [12].

In 1967, Chowduri and Gross proposed two different formula expressions to compute induced overvoltages based on the same assumptions as Rusk, resulting in distinct formulas [13]. In 1968, Liew and Mar modified the Chowduri-Brut approach and introduced their own formula solution [14,15]. Furthermore, the increasing demand for power quality since the early 1990s has prompted numerous specialized numerical studies to address the issue. Some additional studies that have contributed to this field include lightning analysis of 155 kV and 78 kV transmission lines, analysis of lightning overvoltages on power poles using Laplace transform, examination of lightning overvoltages based on pole types, and protection analysis of impulse rods and insulators against overvoltages caused by lightning EM waves [16-19].

In this study, analysis of existing systems, identification of problems and evaluation of solution proposals for lightning protection of buildings in Trakya University, Balkan Campus are carried out. Lightning risk calculations of the buildings, lightning protection radius calculations of the existing protection systems and grounding resistances were determined by measuring the width-length-height of the buildings in the campus. In addition, soil resistance measurements and grounding calculations were made to calculate the protection radii of existing lightning protection systems and measures to be taken for lightning protection within the campus. In this context, lightning protection risk analysis was performed. As a result of this study, 17 of the 29 lightning rods were found to be inappropriate. It was revealed that maintenance-repair-replacement activities of lightning protection systems are not carried out and periodic controls are not carried out.

II. Detection of Lightning Systems

Information about the past records of lightning protection systems was requested by contacting the Department of Construction Works. However, it was determined that the existing lightning protection systems do not have layout plans, risk analysis and past measurement records. As a result of this situation, it was decided that photographic records of lightning protection systems should be created. Thus, using the drone-camera device available at the General Secretariat, Printing and Publishing Unit, photographic records of the external lightning rod components of the lightning protection system in the Balkan Campus were created.

As a result of the imaging study, 29 external lightning rods were identified in Trakya University Balkan Campus. A few examples of photographs of the external lightning rods are presented in Fig. 1. The external lightning arrays are named with the names of the buildings they are located in. In Table 1, the Balkan Campus External Lightning Rod List is shared.

Afterwards, the settlement plans of the Balkan Campus were obtained in consultation with the Department of Construction Works. Existing lightning protection systems were marked on the layout plans and an "External Lightning Protection Layout Plan" was created.

Fig. 1 Balkan Campus Exterior Lightning Photos

Table 1. Balkan Campus External Lightning Rod List

No	Lightning Rods
1	Balkan Oncology Hospital
2	Bolca Main Dining Hall Building
3	Faculty of Dentistry
4	Faculty of Pharmacy
5	Faculty of Literature
6	Faculty of Literature Annex Building
7	Faculty of Science Biology - Mathematics Building
8	Faculty of Science Dean's Office
9	Faculty of Science Physics - Chemistry Building
10	Heat Center
11	Faculty of Economics and Administrative Sciences Amphitheater Building
12	Faculty of Economics and Administrative Sciences Classroom Building
13	Faculty of Theology
14	Kırkpınar Faculty of Sport Sciences
15	Kırkpınar Sports Sciences Faculty Sports Hall
16	Kırkpınar Sports Sciences Faculty Swimming Pool
17	Conservatory Concert Hall
18	Library Building
19	Music and Ballet Middle School
20	Rectorate Building
21	Mental and Nervous Diseases Hospital
22	Faculty of Health Sciences
23	Faculty of Medicine - 1 (right)
24	Faculty of Medicine - 2 (medium)
25	Faculty of Medicine - 3 (left)
26	Faculty of Medicine Amphitheater Block
27	Faculty of Medicine Ratip Kazancıgil Classroom Building
28	Faculty of Medicine Basic Medicine Units Building
29	TÜTAGEM Building

Lightning risk analysis calculations were made for all buildings with external lightning. N_k=35 was determined for Edirne province.

It is seen that $N_d > N_c$ for all buildings. In this context, the implementation of lightning protection system for Trakya University Balkan Campus is determined as mandatory.

As a result, it was revealed that the E value should be calculated for Trakya University Balkan Campus. With the calculated E value, the protection class levels of the buildings were determined. In addition, the protection radius values of the existing lightning protection systems were calculated. In order to better evaluate the coverage area of the calculated protection radius values, necessary drawings were made on the layout plan of Trakya University Balkan Campus and the "External Lightning Protection Coverage Area" diagram was created. Fig. 2 shows the external lightning protection coverage area.

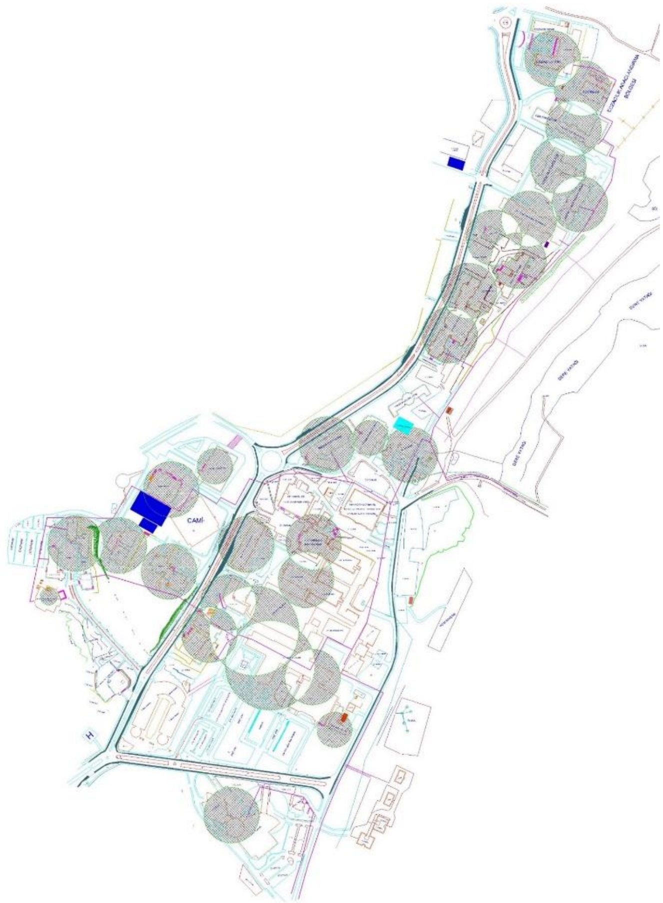

Fig. 2 External Lightning Protection Coverage Areas

III. Grounding Measurements of Lightning Protection Systems

The grounding resistances of the detected external lightning rods are measured with the FLUKE 1623-2 grounding measurement kit shown in Fig 3. Measurement Results are presented in Table 2.

Fig. 3 FLUKE 1623-2 Earth Ground Measurement Kit

In Table 2, R value indicates the grounding resistance value obtained at the end of the measurement and S value indicates the compliance status. A stands for appropriate and IA stands for inappropriate.

Table 2. Balkan Campus External Lightning Grounding Resistance Values

No	Lightning Rods	R	S
1	Balkan Oncology Hospital	4.84 Ω	A
2	Bolca Main Dining Hall Building	17.88 Ω	IA
3	Faculty of Dentistry	7 Ω	A
4	Faculty of Pharmacy	5.43 Ω	A
5	Faculty of Literature	Not Measured	IA
6	Faculty of Literature Annex Building	Not Measured	IA
7	Faculty of Science Biology - Mathematics Building	Not Measured	IA
8	Faculty of Science Dean's Office	9.27 Ω	A
9	Faculty of Science Physics - Chemistry Building	Not Measured	IA
10	Heat Center	4.74 Ω	A
11	Faculty of Economics and Administrative Sciences Amphitheater Building	9.38 Ω	A
12	Faculty of Economics and Administrative Sciences Classroom Building	244 Ω	IA
13	Faculty of Theology	17.95 Ω	IA
14	Kırkpınar Faculty of Sport Sciences	76.6 Ω	IA
15	Kırkpınar Sports Sciences Faculty Sports Hall	Not Measured	IA
16	Kırkpınar Sports Sciences Faculty Swimming Pool	Not Measured	IA
17	Conservatory Concert Hall	8.2 Ω	A
18	Library Building	Not Measured	IA
19	Music and Ballet Middle School	7.37 Ω	A
20	Rectorate Building	67 Ω	IA
21	Mental and Nervous Diseases Hospital	Not Measured	IA
22	Faculty of Health Sciences	11.74 Ω	IA
23	Faculty of Medicine - 1 (right)	10.37 Ω	IA
24	Faculty of Medicine - 2 (medium)	3.17 Ω	A
25	Faculty of Medicine - 3 (left)	2.71 Ω	A
26	Faculty of Medicine Amphitheater Block	5.5 Ω	A
27	Faculty of Medicine Ratip Kazancıgil Classroom Building	4.43 Ω	A
28	Faculty of Medicine Basic Medicine Units Building	Not Measured	IA
29	TÜTAGEM Building	Not Measured	IA

IV. Discussion

Descriptions of the external lightning installations classified as "Inappropriate" are presented in Table 3.

Table 3. External Lightning Assessment Results

No	Lightning Rods	Commentary
2	Bolca Main Dining Hall Building	High Resistance
5	Faculty of Literature	Test terminal ineffective
6	Faculty of Literature Annex Building	Oxidation
7	Faculty of Science Biology - Mathematics Building	Oxidation
9	Faculty of Science Physics - Chemistry Building	No favorable conditions
12	Faculty of Economics and Administrative Sciences Classroom Building	High Resistance
13	Faculty of Theology	No earth connection
14	Kırkpınar Faculty of Sport Sciences	High Resistance
15	Kırkpınar Sports Sciences Faculty Sports Hall	Oxidation
16	Kırkpınar Sports Sciences Faculty Swimming Pool	No test terminal
18	Library Building	Oxidation
20	Rectorate Building	High Resistance
21	Mental and Nervous Diseases Hospital	No test terminal
22	Faculty of Health Sciences	High Resistance
23	Faculty of Medicine - 1 (right)	High Resistance
28	Faculty of Medicine Basic Medicine Units Building	Oxidation
29	TÜTAGEM Building	Test terminal ineffective

Details of the negative conditions and nonconformities identified are shared in Fig. 4.

Fig. 4 Detected adverse conditions and inappropriates

V. Conclusion

This study aimed to develop a lightning impulse generator that is suitable for use in the High Voltage Laboratory of Yildiz Technical University. Changes were made to the structure of the impulse voltage generator to allow the application of lightning impulse voltage consecutively every 15 seconds.

In the Physics-Chemistry building, access to the test terminal was not possible.

The recently completed Faculty of Theology building was found to have no electrical connection between the external lightning rod and the ground.

It was observed that there were no test terminals in the Mental and Nervous Diseases Hospital and Swimming Pool buildings.

In the TÜTAGEM building, it was determined that a single conductor was used instead of two separate conductors that should be joined in the test terminal. In this case, the test terminal loses its function.

In buildings such as the Faculty of Letters, Faculty of Science and Basic Medicine Units, test terminals could not be removed due to oxidation.

In the Rectorate building, it was observed that the test terminal was located on the roof. This makes the measurement process very difficult.

In addition, when the external lightning rod photographs are evaluated considering the building construction years, it is suspected that the 10 external lightning rods listed below are RADIOACTIVE.

- Bolca Main Dining Hall Building
- Faculty of Letters (2 Units)
- Physics - Chemistry Building
- Biology - Mathematics Building
- Faculty of Economics and Administrative Sciences (2 Units)
- Kırkpınar Faculty of Sport Sciences
- 75th Year Indoor Sports Hall
- Conservatory Concert Hall

Furthermore, as seen in Fig. 2, it is clear that the protection coverage areas do not cover all buildings in the Balkan Campus. It was determined that some buildings do not have lightning protection systems.

In the light of the findings, it has been determined that there is no record of the lightning protection systems of the Balkan Campus and periodic measurements and controls are not carried out. In this context, it is necessary to check the lightning protection systems of all campuses, including Trakya University Balkan campus, and to make the inappropriate installations appropriate. After the completion of these processes, periodic measurements should be made and recorded and lightning protection systems should be monitored regularly and continuously.

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