ЕНЕРГЕТИКА СТАЛОГО РОЗВИТКУ
SUSTAINABLE ENERGY

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PECULIARITIES OF LIGHTNING PROTECTOR OF GROUND SOLAR POWER PLANTS IN UKRAINE

One of the most promising and developing areas in the energy sector is development of renewable energy sources. Among others technologies of solar energy and wind power are the fastest to develop in the sector. That is why solar power plants are under discussion in this paper. The increase in the Solar Power Plant's capacity in Ukraine from 2018 to 2020 reached 7 times. Problems that may interfere with the functioning of the ground solar power plants are considered as this technology covers large areas of land and is on the 1st place on the amount of lightning strikes among the renewables. Ways to solve the problems associated with the damage from direct lightning strikes for ground solar power plants are discussed in this paper. Active and passive types of lightning protection for inland solar power plants are investigated and their modeling is carried out and presented in this paper. The measures proposed in this paper based on the implementation of an active lightning protection system ensure uninterrupted operation of the ground solar power plants, avoid reduction of service life and unnecessary economic costs for the replacement of damaged photovoltaic modules, reduced costs related to complexity of installation of passive system in comparison to active lightning protection system.

Keywords: *renewable energy sources, solar power plants, lightning protection, direct lightning strikes, passive lightning protection, active lightning protection, SWOT-analysis.*

Introduction. The Ukrainian energy sector seeks to change its operating policy by focusing on European Union's solutions and innovations in the development of renewable energy sources (RES). According to the "New Energy Strategy of Ukraine until 2035: security, energy efficiency, competitiveness" reforms that will increase the share of RES to 25% in Ukraine are planned [1]. This will make Ukraine's energy sector attractive to foreign investors, reduce the share of harmful emissions and be a step towards the implementation of Directive 2010/75 / EU on industrial emissions into Ukrainian legislation.

The increase in the Solar Power Plant's (SPP) capacity in Ukraine from 2018 to 2020 reached 7 times. The installed capacity of SPP in January 2020 was 5300 thousand MW [2]. From these data we can conclude that solar energy is a popular type of RES in Ukraine. Ukraine's geographical location and climatic zones allow the construction of SPP and the development of this segment in RES sector, but in some southern and eastern regions the risk of lightning striking a solar station is significantly higher (see Figure 1).

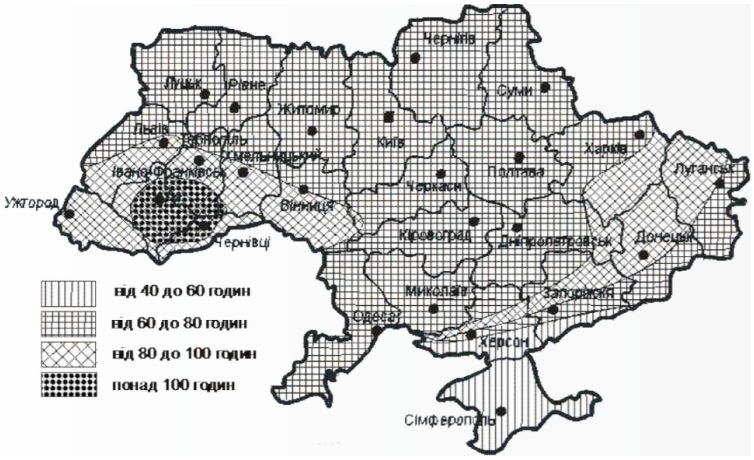

Figure 1 - Map of the average duration of thunderstorms per year in hours in Ukraine [3]

Lightning strikes in ground-based SPP can cause mechanical damage to equipment, fire and explosion, Ohmic heating of conductors, release of hazardous products - hazardous chemicals, electric shock to humans and animals due to contact voltage and step voltage, so lightning protection is an important solution in SPP.

Purpose of this paper: to investigate the work of active lightning protection and to carry out modeling on the example of the designed SPP. To present the solutions to improve the lightning protection system of SPP. To carry out a SWOT-analysis of the selected lightning protection system.

Tasks to achieve the purpose: to study the structure and operation of lightning protection systems; to implement active lightning protection system for ground SPP.

1. The structure of lightning protection

The system of protection against direct lightning strikes includes:

1. Lightning receiver - part of the structure of the lightning rod (usually made of aluminum, steel and copper,), which intercepts lightning and takes a direct hit, directing the lightning current to the underground part of the lightning rod - grounding. Lightning rods can consist of any combination of the following elements: rods, taut wires (cables), mesh conductors (nets).

2. Earthing conductors - metal or reinforced concrete structures of buildings, structures, external installations, and lightning rod supports, which stand alone, etc., which are in contact with the ground.

3. Current arrester - part of the lightning arrester structure which is designed to divert lightning current from the lightning rod to the ground and is laid in straight and vertical lines so that the path was the shortest. [3]

2. Passive lightning protection of ground SPP

Considering the operation of passive lightning protection on the example of SPP designed in the framework of the bachelor's project K. Hilevich, on the topic "Organization of lightning protection and grounding of a ground solar power plant." Lightning protection was provided for the ground SPP of industrial purpose, which is located in the Kyiv region. In order to protect the SPP from direct lightning strikes (DLS) it was proposed to use single rod lightning protection system, lightning rod on the crest of the company LEO LIGHTMAN M10 / 09. [4] (see Fig. 2).

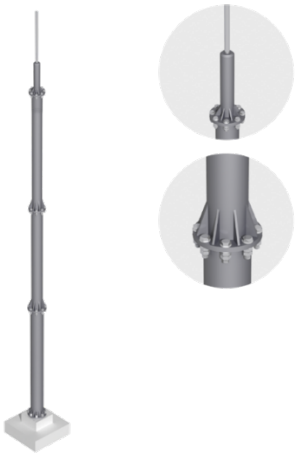

Figure 2 - Lightning rod on the crest of LEO LIGHTMAN M10 / 09

The model of the rod lightning protection system of the designed SPP is shown in Figure 3:

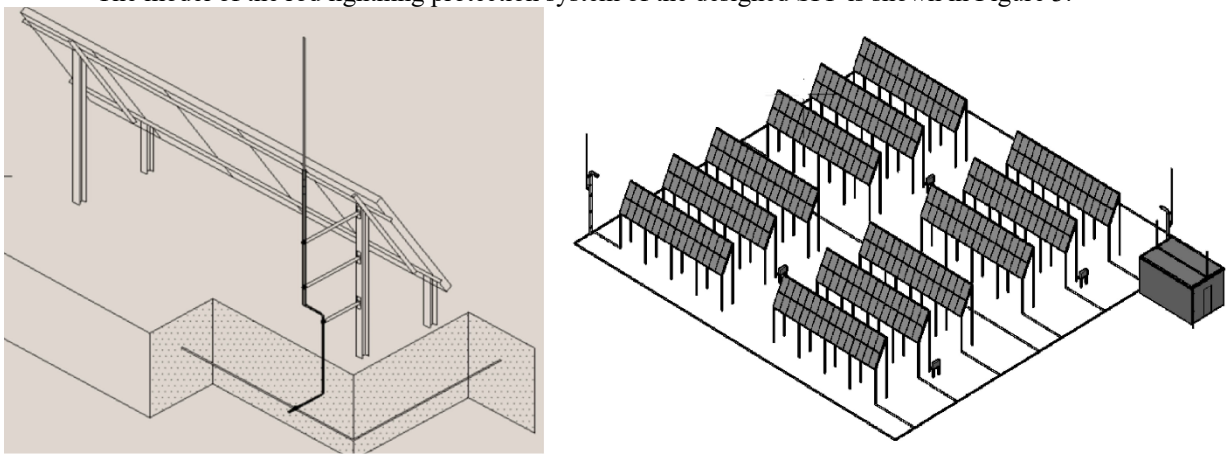

Figure 3 - Model of the system of rod lightning protection of ground SPP

The initial data of the lightning protection calculation of the designed SPP are given in Table 1. The radius of the protective cosine was determined by the method of the radius of the protective cone of a single rod lightning rod for the outer protection areas of the double rod lightning rod system.

Table 1 - Initial data for the calculation of lightning protection of the designed SPP

Indexes	
Lightning protection level (LPL)	I
The total area of SPP-1, m^2	3557
Lightning rod height, m	4,4
Total height of the structure, m	6,8
Total rods, pieces	80
Reliability of protection against DLS	0,9

The radius of the horizontal section of the protection of a single rod lightning rod is according to the formula:

$$r_x = \frac{r_0 \cdot (h_0 - h_x)}{h_0},$$

where r_0 – the radius of the cone on the earth's surface;
h_0 – the height of the cone;
h_x. – lightning rod height.

The radius of the protective cosine of designed and examined SPP is:

$$r_x = \frac{8{,}16 \cdot (5{,}78 - 2{,}4)}{5{,}78} = 4{,}76$$

Protection zone of rod lightning rods for ground SPP is shown in Fig. 4.

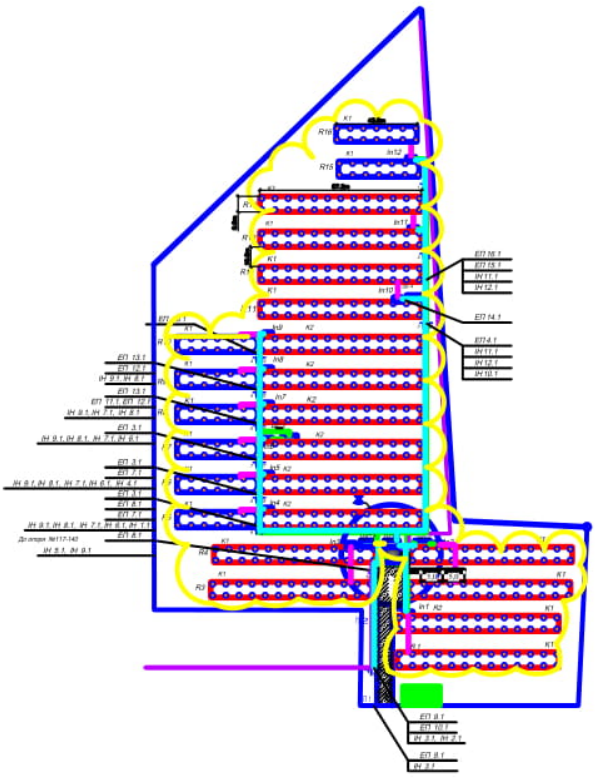

Figure 4 - Zone protection zone of lightning rods for ground SPP

3. Modern active lightning protection to replace passive

Today, technologies are rapidly evolving, improving systems for protection against overvoltage and short-circuit currents, and so on. But the factor influencing the equipment, especially SPP such as weather conditions (especially lightning), has not disappeared. Passive lightning protection is not very relevant now, given that there is already active lightning protection systems on the market.

Figure 5 - Active lightning receiver [5]

To implement active lightning protection, a SWOT-analysis of the latest protection against DLS SPP was conducted (see Tab. 2).

Table 2 - SWOT-analysis of active lightning protection system for SPP

Strengths:	**Weak sides:**
• Principle of operation: the electronic system causes ionization much earlier and with greater intensity • Radius of protection of one current collector to 100 m • The protection zone has the form of a capsule • Installation, maintenance and repair are proportional to the number of system elements • Low complexity of installation	• The cost of upgrading the old lightning protection system • Imperfect documentation base for design and operation
Opportunities:	**Threats:**
• Lightning protection of any type of objects • Support for domestic producers • Installation of modern equipment	• Lightning unpredictability • Impossibility of 100% protection

Based on the SWOT-analysis, we can conclude that the introduction of an active lightning protection system SES is appropriate. Single active lightning rods, GROMOSTAR 60 and GROMOSTAR 45 crest lightning rods will be used to protect against DLS. [6]

Data on the category of protection and the area of SPP are given in table 1. The protection radius of one active current collector is specified in the catalog.

The area of protection of active lightning rods for ground SPP is shown in Figure 6.

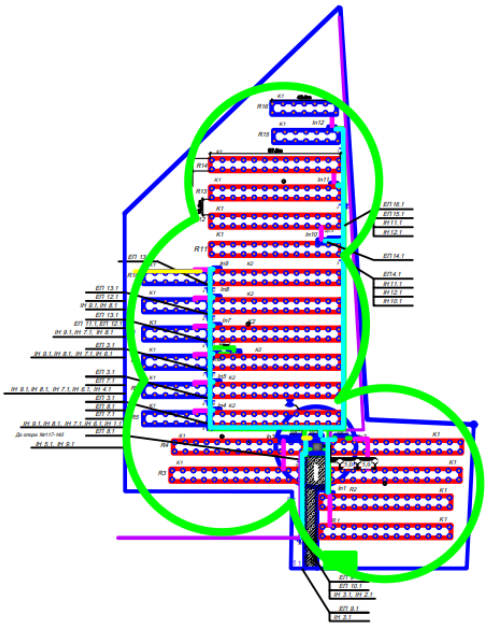

Figure 6 - Zone of protection of active lightning rods for ground SPP

Conclusion: The proposed measures to implement an active lightning protection system ensure uninterrupted operation of the ground SPP, avoid reduction of service life and unnecessary economic costs for the replacement of damaged photovoltaic modules, reduced costs related to complexity of installation of passive system in comparison to active.

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ОСОБЛИВОСТІ БЛИСКАВКОЗАХИСТУ НАЗЕМНИХ СОНЯЧНИХ ЕЛЕКТРОСТАНЦІЙ В УКРАЇНІ

Одним з найбільш перспективних напрямків у енергетичному секторі є розвиток відновлюваних джерел енергії. Серед інших, технології сонячної енергетики та технології вітроенергетики найшвидше розвиваються у цьому секторі. Ось чому сонячні електростанції розглянуто у цій роботі. Збільшення потужності сонячних електростанцій в Україні з 2018 по 2020 роки склало близько 7 разів. Розглянуто проблеми, які можуть заважати функціонуванню наземних сонячних електростанцій, оскільки ця технологія охоплює значні площі посідає 1-е місце за кількістю ударів блискавки серед відновлюваних джерел енергії. Шляхи вирішення проблем, пов'язаних з пошкодженням від прямого удару блискавки наземних сонячних електростанцій, обговорюються в цій роботі. Досліджено активні та пасивні типи блискавкозахисту для наземних сонячних електростанцій, проведено та представлено їх моделювання. Заходи, запропоновані в цій роботі, засновані на впровадженні активної системи блискавкозахисту, забезпечують безперебійну роботу наземних сонячних електростанцій, уникають скорочення терміну служби та зайвих економічних витрат на заміну пошкоджених фотоелектричних модулів, зменшують витрати, пов'язані зі складністю установки пасивної системи порівняно з активною системою блискавкозахисту.

Ключові слова: *поновлювані джерела енергії, сонячні електростанції, блискавкозахист, прямі удари блискавки, пасивний блискавкозахист, активний блискавкозахист, SWOT-аналіз.*

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