Advanced Strategies for Surge and Lightning Protection in Photovoltaic Parks

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The fundamental theoretical aspects of protecting photovoltaic parks against lightning and overvoltages. From an overview of photovoltaic systems, attention is focused on their ability to generate electricity from solar radiation. Lightning, its occurrence, and associated effects, such as electrical surges, are discussed below. Lightning effects in photovoltaic installations were examined, and thermal, electrodynamic, and combustion-related consequences were described in detail. Electric overvoltage was introduced, dividing it into permanent and temporary, as well as the associated risks. The possible implications of overvoltages on solar farms are analyzed, ranging from economic losses to impacts on life and property. It highlights the critical role of the Earth system as a preventive measure and explains its purposes, classification, and design requirements. The crucial role of grounding devices (Class I and II) and circuit breakers in ensuring adequate protection is explained. The practical application of this information is justified by the need to minimize the risks of lightning and overvoltage, to ensure the safe and efficient operation of photovoltaic parks and, simultaneously, to protect life, property, and economic resources.

Installing photovoltaic parks involves significant costs, and their operational efficiency and durability depend largely on an effective security system. The electrical engineering companies are responsible for planning, calculation, and installation to comply with national and international electricity distribution standards. The strategic location of solar panels and inverters is analyzed, including specific insulation and colour coding. The protection system analysis highlights the importance of preventing surges by providing a three-stage protection system from the general distribution center to the investor's entrance. Specific protection devices, such as surge protectors and circuit breakers, are detailed at each level. Emphasis has been placed on keeping resistances low to ensure a safe installation. Emphasis is placed on using vertical electrodes, appropriate connections and detailed connections to substations and underground wells. Equally important is the equalization of potential between the solar panel tables and the structures, achieved through conductor plates and connections to the ground grid. This part also addresses the protection against direct lightning falls, proposing the installation of lightning arresters on awnings and poles to improve the protective coverage of the entire park. Despite rising costs, a proposal for an advanced tip collection system has been put forward, stressing its importance in preventing catastrophic damage and ensuring security. Therefore, the in-depth analysis highlights the importance of taking step-by-step steps to ensure the efficiency and safety of PV parks.

The Proposals for Improvement and Development of Technological Tools cover the weaknesses in designing the direct lightning protection system and grounding networks in photovoltaic parks. To address these challenges, a new grounding network design was developed using software from SERVICIOS Tecnológica S.A. suggested. In addition, the FOTOPROT application developed in MATLAB, which simplifies the design of a parking safety tower system, was presented.

For the Ground grid proposal for photovoltaic parks, A groundbreaking improvement in the configuration of grounding grids for protection against direct lightning strikes in photovoltaic parks is proposed. Existing grids in some parks involve two rings of horizontal electrodes connected to metallic structures supporting solar panels. Simulation results illustrate the proposed changes, demonstrating a significant reduction in transient potentials, mainly when introducing a discharge at node 1. The maximum potential value at the discharge node is approximately 24kV, less than half of the previous configuration. Potentials decrease as they penetrate the park, reaching values below 2kV. Given the considerably lower transient peaks, these substantial differences underscore the importance of reinforcing surge protection elements.

FOTOPROT is introduced as a sophisticated technical tool featuring a graphical interface. With robust calculation capabilities, FOTOPROT enables the inputting of crucial data for PV farm design and calculates the necessary mast system for installation protection. The application facilitates a graphical representation of the mast layout and resulting protection areas. Combining calculation and visualization functionalities provides a comprehensive solution for planning and optimizing PV farm protection against adverse events, ensuring efficiency and safety.

The theoretical foundation of FOTOPROT described in this segment is based on the Electrogeometric Model. According to this model, the impact distance of a beam, which is the distance over which the stepped guide is attracted to impact a target, is directly proportional to the charge density of the stepped guide. In addition, the current in the subsequent return discharge is proportionally related to the charge density of the preceding guide, this return current being a measurable parameter.

When protection is implemented using a simple mast, the attraction area is configured as a sphere segment above the earth attraction area, as depicted in Figure 1. In this case, an impact occurs if the discharge passes through this spherical segment.

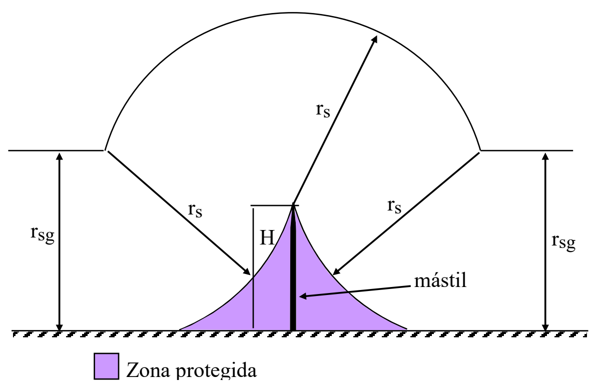

Figure 1. Attraction area and protection zone of a single mast.

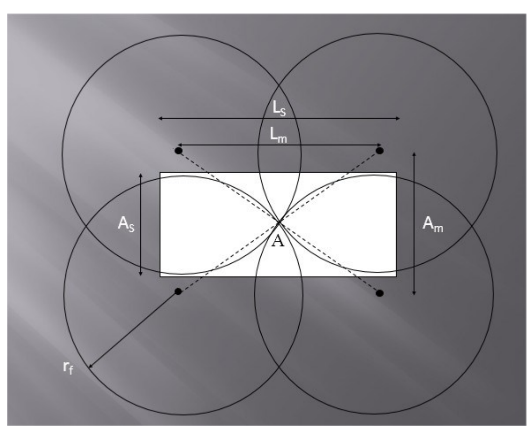

Figure 2. Rectangular area protected by four masts.

To protect a rectangular area with dimensions of width (As) and length (Ls), vertical masts and rows of masts covering the designated area are used. In this scenario, the width between two rows of masts (Am) equals the width of the active bar structures, plus twice the minimum distance between the functional parts and the grounded objects, i.e. AS + 2 Sb. The distance between two adjacent masts of the same row (Lm) is illustrated in Figure 2, where four masts are used to protect the area.

To completely protect the rectangle (Ls As), the spheres must cover the entire area, implying that the radius rf circles must overlap without leaving space between them. However, there are other conditions for complete protection. The section below point A in the figure, where the two diagonals intersect, represents the masts' furthest point within the protected area. At this point of interception, which is closest to the ground plane, the height of the area of attraction provided by the mast at point A must be greater than the area of attraction of the ground plane [12].

Computational applications represent an efficient tool to expedite calculations in solving specific problems. GMAT's use in ground grid design and transient potential analysis against atmospheric discharges reveals notable disparities between the installed and proposed models, showcasing a significant decrease in potential values for the suggested grid. FOTOPROT, another noteworthy application, is a specialised calculation tool for determining the necessary mast system to ensure the integral protection of a Photovoltaic Park. Its development is rooted in the Electrogeometric Model, specifically addressing mast protection in defined areas. With its simple interface, this software can graph the results, an essential feature in any design process. Economic considerations should be considered, and it is imperative to thoroughly analyse potential losses associated with the lack of protection in the installation, underscoring the importance of addressing economic aspects in any proposal.

The comprehensive analysis of solar farm protection focuses on overvoltages, grounding systems and lightning protection. An exhaustive literature search on photovoltaic farms provided a solid basis for the analyses and suggestions presented. A detailed analysis of surge protection systems highlighted their effectiveness and technologies and identified challenges posed by grounding systems. An evaluation of the direct lightning protection system revealed the limits of the overall protection of the park area and prompted suggestions for improvement. An optimised grounding network configuration for interconnected circular farms was presented, demonstrating a significant reduction of transient short-circuit potentials. As a practical result, FOTOPROT was developed, an intuitive graphical user interface that allows calculating protection against direct lightning falls on poles and represents a global solution to protect the entire area of a photovoltaic park. This contribution provides significant advances in understanding and improving the safety of solar farms and highlights the importance of implementing effective and efficient solutions in this critical area of electrical engineering.

REFERENCES

Fermosell, R. S. (2013). El exito de la energia solar fotovoltaica en Cuba. Available: http://www.suelosolar.com/newsolares/newsol.asp?id=8935

Chavez, I. (2015). Desarrollo en Cuba de la energía solar fotovoltaica. Recuperada de http://www.enginyeria-classea.cat/

GOMEZ, C. C. Sistema De Energia Solar Fotovoltaica Conectado A Red Para Generacion. GRADO EN INGENIERIA ELECTRICA, DEPARTAMENTO DE INGENIERIA ELECTRICA, UNIVERSIDAD CARLOS III DE MADRID ESCUELA POLITECNICA SUPERIOR, MADRID 2012. Available: https://e-archivo.uc3m.es/

Engineering. (2010). RECOMENDACIONES GENERALES PARA LA PROTECCION DE LOS SISTEMAS FOTOVOLTAICOS AISLADOS CONTRA LAS DESCARGAS ATMOSFERICAS Available: http://renewablengineering.blogspot.com

Hernández, J. C., et all. (2008). Lightning and surge protection in photovoltaic installations. IEEE Transactions on power delivery, 23(4), 1961-1971. Available: https://www.researchgate.net/publication/3276537_Lightning_and_Surge_Protection_in_Photovoltaic_Installations

Hernández, Y. y Santana, W. (2002). DISEÑO DE PUESTA A TIERRA EN SISTEMAS ELECTRICOS"., Facultad de Ingeniería Eléctrica, Universidad Central ´´Marta Abreu´´ de Las Villas., Cuba, 2002.

Blanco Sardinero, I. (2009). Instalación solar fotovoltaica conectada a red sobre la azotea de una nave industrial (Bachelor's thesis). Available: e-archivo.uc3m.es

DEHN IBÉRICA Protecciones Eléctricas, S.A. Unipersonal. (2015). DEHNguard® modular con fusible integrado. Available: http://www.dehn-international.com/DEHNguard® modular con fusible integrado _ DEHN Spain/

DEHN IBÉRICA Protecciones Eléctricas, S.A. Unipersonal. (2015). BLITZDUCTOR® VT. Available: http://www.dehn-international.com/BLITZDUCTOR® VT _ DEHN International/

INEL(2012). Sistema Electrico de Fuerza, Alumbrado, Tierra y Pararrayos, ed. Cienfuegos 2012.
Rojas (2007). Proteccion de Subestaciones, ed, 2007.