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ORIGINAL ARTICLE

Method for inspection of atmospheric discharge protection systems: Grain storage plants[1]

Método para inspeção de sistemas de proteção de descargas atmosféricas: Plantas de armazenamento de grãos

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HIGHLIGHTS:
Using unmanned aerial vehicles to inspect atmospheric discharge protection systems eliminates the risk of worked falling.
By the inspection method is possible to prioritize the elements and sites needing maintenance.
Maintenance activities at height can be planned through the use of Remotely Piloted Aircraft System.

ABSTRACT: Brazil has the highest incidence of atmospheric discharges, on average of 77.8 million hitting the country yearly. Companies providing post-harvest services have a high monetary value concentrated in their predominantly metallic structures. Atmospheric discharge protection systems (ADPS) are used in this context to protect the facilities and people, composed of several elements that require visual inspection with a certain periodicity, an activity framed as working at height. This research aimed to establish a methodology for employing a Remotely Piloted Aircraft System (RPAS) in the visual analysis of the operational condition of external atmospheric discharge protection systems components located in grain storage structures to collect information during the preliminary risk analysis and planning of activities at height. A survey of the current literature related to the subject was carried out, in addition to the norms, inspection agencies, and operational prerequisites of this type of equipment in the national territory. Finally, a method was created and validated based on the inspection checklist with the main points for checking, which generates a score that represents the urgency level of intervention, applied in a unit located in western Paraná, Brazil, on 11/28/2022. This procedure eliminated the risk of workers falling during the planning and inspection stage of the structures, which helped the qualified professional to issue the technical inspection report more quickly. The disadvantage is related to the dependence on favorable weather conditions.

Key words: work at height, drone, unmanned aerial vehicles

RESUMO: O Brasil é o país com a maior incidência de descargas atmosféricas, em média 77,8 milhões atingem o país todos os anos. As empresas prestadoras de serviços pós-colheita possuem um elevado valor monetário concentrado em suas estruturas, que predominantemente são metálicas. Os sistemas de proteção contra descargas atmosféricas (SPDA) são utilizados neste contexto para realizar a proteção das instalações e pessoas, os quais são compostos por vários elementos que necessitam de inspeção visual com determinada periodicidade, atividade enquadrada como trabalho em altura. Esta pesquisa tem como objetivo estabelecer uma metodologia para o emprego de Remotely Piloted Aircraft System (RPAS) na análise visual das condições operacionais dos componentes de um sistema de proteção contra descargas atmosféricas externo, localizados em estruturas de armazenamento de grãos para coletar informações durante a análise preliminar de riscos e planejamento das atividades em altura. Realizou-se um levantamento da atual literatura relacionada ao assunto, além das normas, órgãos fiscalizadores e pré-requisitos operacionais deste tipo de equipamento em território nacional. Por fim, foi criado e validado um método com base no checklist de inspeção com os principais pontos para conferência, que gera uma pontuação que representa o nível de urgência de intervenção, aplicado em uma unidade localizada no oeste do Paraná, Brasil, em 28/11/2022. Este procedimento eliminou o risco de queda do trabalhador na etapa de planejamento e inspeção das estruturas, o que auxiliou o profissional habilitado a emitir o laudo técnico de vistoria com maior agilidade. A desvantagem relaciona-se à dependência das condições climáticas favoráveis.

Palavras-chave: trabalho em altura, drone, veículos aéreos não tripulados

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Introduction

Brazil ranks first in the world in the incidence of electric discharges. The Atmospheric Electricity Group - ELAT of the Instituto Nacional de Pesquisas Espaciais – INPE reports that an average of 77.8 million electrical discharges strike the country annually; It is estimated that 100 million lightning strikes per year will strike the national territory around 2081, in accordance with the increasing trend and evidence of climate change, which can severely affect installations, equipment and people (Costa, 2022). To reduce the damage due to atmospheric discharges and protect industrial, commercial and residential establishments, the use of Atmospheric Discharge Protection Systems (ADPS) is necessary (ABNT, 2015; Patrício, 2016).

During the period from 2000 to 2019, 2,194 fatalities occurred, with an average of 110 cases of death per year, with the highest percentages being associated with agribusiness activities (26%) (ELAT, 2020; Bellochio & Coradi, 2022).

All buildings and metallic structures for handling and storing agricultural products must have a protection system against atmospheric discharges and static energy generated to prevent damage and accidents, whose inspection and maintenance are framed as work at height. In this context, the use of unmanned aerial vehicles in risk recognition and mapping is growing, making them a very useful tool in accident prevention (ABNT, 2015; Lopes et al., 2020).

This research aimed to establish a methodology for employing a Remotely Piloted Aircraft System (RPAS) in the visual analysis of the operational condition of external ADPS components located in grain storage structures to collect information during the preliminary risk analysis and planning of activities at height.

Material and Methods

For the research development, a survey of the current state of the literature was initially performed to prepare the checklist and verify the Remotely Piloted Aircraft System (RPAS) equipment and its documentation in the national territory. The inspections and planning of maintenance activities were performed on 11/28/2022 at 10:30 a.m. in a grain storage and drying unit in the Western region of Paraná, Brazil, at the geographic coordinates of 25° 18’ 17” S and longitude 54° 05’ 32” W, at an altitude of 433,26 m. The selection criteria were established as the unit that had the longest period of activity and the amount of product processed/stored during the harvest period.

It was used the systematic literature review method, Methodi Ordinatio, proposed by Pagani et al. (2018), to classify the papers found according to their relevance.

The first step was to select the keywords related to the research topic: inspection, labor inspection (I); work at height, height (II); RPAS, drones, unmanned aerial vehicle, aircraft, Unmanned Aerial Vehicles (UAV) (III); storage facilities, grain storage units, grain operations, grain storage facilities, grain silo (IV); arrester, ADPS, Atmospheric Discharge Protection Systems (V). The keywords were combined using Boolean variables, and the exploratory research was done in the Scopus, Science Direct, Web of Science, and SciELO databases.

Filters were used as search criteria to delimit the temporal space to a range between 2019 and 2022, and as for the type of document, only those classified as articles were chosen (Pagani et al., 2018). The number of papers obtained by applying the filters was 181 articles. The filtering procedures eliminated papers with no abstract and/or authors, duplicate works, and subjects outside the theme, resulting in 28 selected articles.

The articles were submitted to the RankIn method, presented by Pagani et al. (2018), which aims to rank the studies found, identifying the most relevant ones. Such a procedure was used to obtain the current state of the art of the proposed research.

To develop the checklist, it was considered the points that can be visually inspected in the ADPS contained in NBR:5419, NR 10, NBR 5410, and NPT27-2, subdividing it into four topics, respectively: project, lightning rod, insulators, and cabling, as shown in Table 1.

From the 15 questions that compose it, question 1 refers to checking the existence of the ADPS project and whether it is up to date. Every ADPS must be designed and installed under the responsibility of a duly qualified professional, and it is the company’s responsibility to keep this documentation updated (ABNT, 2015).

Questions 2 to 5 - lightning rods and 6 to 9 - down system (insulators), the conditions of fixation, deformations, cracks, oxidation, corrosion, and rust are identified. Lightning rods: The lightning rods should be inspected regardless of the protection method used (Franklin or Faraday) since they make up the part of the system where the rays fall directly. Due to natural conditions and factors caused by the power of lightning discharges, someone must pay attention to points such as oxidation or corrosion, whether they are well attached or have physical deformation, to avoid malfunction or loss of

Table 1. Points evaluated during the inspection

Questions	Project
1	Is the design up to date and correctly represents the installed atmospheric discharge protection systems?
	Lightning rod
2	Do they have good fixation characteristics?
3	Are there no cracks or melting points?
4	Free of oxidation points, corrosion, or rust?
5	Without the physical alterations (twisting, missing some component)?
	Down system (insulators)
6	Are the insulators properly fixed?
7	Are they exempt from any physical alteration?
8	No oxidation or corrosion points on the insulators?
9	Are the rubbers undamaged and not cracked?
	Down system (Cabling)
10	Are the cables not in contact with any part of the structure (except insulators)?
11	Are the cables well tensioned?
12	Are they free of dirt (putty, resins, paints) that could compromise the system?
13	Do the down conductors have no connections or splices?
14	Are the connections or splices integral with no oxidation or corrosion points present?
	Complementary protection devices
15	Is there a complementary inspection device installed or procedures performed?

efficiency. Insulators: are a fundamental part of the discharge conduction and descent system. Failures such as oxidation points, torsion, and wear and tear of the insulating rubbers are commonly found, presenting risks of accidents such as energization of the facilities (contact between the cable and the structure), which can cause damage to equipment and living beings (ABNT, 2015).

In questions 10 to 14 - Down system (cabling), the integrity of the cables used to conduct the electrical discharges is observed, i.e., if they are tensioned, without contact with parts of the structure and with the minimum possible connections with the presence of oxidation and/or corrosion, because these are subject to breakage in cases of corrosion or poorly stretched (ABNT, 2015).

Complementing the points mentioned above, it is necessary to check the quality of the equipotentialization connections between metallic structures, joints, and connections (electric or exothermic welding and mechanical compression or pressure connections), and they cannot be present in the downstream cabling and check that the inspection boxes are clean and the terminals and connections not oxidized (ABNT, 2015).

Question 15 - Complementary protection devices refer to the existence of devices or procedures performed in addition to what is foreseen in the norm.

During the inspection, items that do not conform to the norm are assigned the word “NO”, with a score of zero. Conforming items are assigned the word “YES” or “NOT APPLICABLE”, the weight of each question corresponding to the maximum score that can be obtained in the evaluation (100 points) divided by the number of items evaluated (14). Question 15 - Complementary Protective Devices is worth four points and generates a bonus score, giving a maximum evaluation score of 104 points.

Different weights can be given to each item evaluated according to its importance. In this study, 30 points were stipulated for question 1, and for questions 2 to 14, a weight of 5.38 (70/13) was stipulated. The questions were prepared based on NBR:5419, NR 10, NBR 5410 and NPT27-2, and had the participation of two electrical engineers to prepare the questions and distribute the scores.

The checklist generates a score and must be interpreted following the precepts below.

An evaluation indicator was used to verify the urgency level of adequacy of the identified risk situations, prioritizing the most critical ones. The risks described above were evaluated qualitatively and quantitatively following the legislation.

The score obtained defines how well that item complies with the legislation and is presented as an evaluation indicator. Points from 0 to 40: critical level and adjustments should be carried out urgently; from 41 to 60: alert level and adjustment are recommended; from 61 to 80 points: regular level, in good condition but with some restrictions to the norm; from 81 to 104: normal level, in good condition, with few or no restrictions to the norm.

The application of each checklist generated a score that evidenced the situation of the respective risk at the site evaluated, and based on the score obtained, it was possible to individually assess the risks and propose an action plan to help resolve the nonconformities identified, prioritizing those with more critical levels.

A DJI Mavic Pro quadcopter RPAS, Figure 1, owned by the Federal Technological University of Paraná (Universidade Tecnológica Federal do Paraná – UTFPR), Campus of Medianeira, was used to perform the ADPS inspection activities.

The equipment has a camera that records videos in 4K (3840 × 2160 px) and captures images at 12 Mpx. It must meet a series of prerequisites so that its use follows that established by the regulatory agencies and can be used in the field.

Currently, three agencies are responsible for regulating RPAS in Brazil: the National Telecommunications Agency (Agência Nacional de Telecomunicações - ANATEL), the National Civil Aviation Agency (Agência Nacional de Aviação Civil - ANAC), and the Department of Airspace Control (Departamento de Controle do Espaço Aéreo -DECEA).

First, the weight of the device was identified (730 g), which according to this characteristic, fits into class 3, which determines some operational requirements, such as the need for pilot qualification. The next step was to verify the homologation of the radio frequency used by the communication components, which was done by checking the presence of the ANATEL seal on the bottom of the battery (ANAC, 2021).

Before registering the pilot, it is necessary to perform the RPAS certification at ANAC through the Unmanned Aircraft Systems platform (Sistema de Aeronaves não Tripuladas – SISANT). The equipment was registered as belonging to the Federal Technological University of Paraná (UTFPR), a legal entity, upon presentation of documents such as the invoice and images of the device.

After registering in the ANAC system, it is required that the RPAS is linked to the Request for Access for Remotely Piloted Aircraft (Solicitação de Acesso de Aeronaves Remotamente Pilotadas – SARPAS), an agency controlled by DECEA. To meet this requirement, the certificate previously issued by SISANT and some data related to the legal entity was presented on the platform as registration requirements.

Figure 1. Dà-Jiāng Innovations Science and Technology (DJI) Mavic Pro quadcopter Remotely Piloted Aircraft System (RPAS)

Once these steps are completed, the pilots must register at SARPAS, which is done by presenting an official document with a photo. Then the person responsible for the RPAS (legal entity) can share the equipment with the operators to meet the norms and legislation.

For each operation performed, the pilot must make a flight request through his profile in the SARPA system before submitting the aircraft code used and the location, altitude, and duration period.

The mandatory documentation to be carried out by the operator comprises the certificate of ANAC, the flight manual, a personal identification document with a photo, the equipment invoice, and the operational risk assessment (ANAC, 2021).

Since the RPAS is classified as class 3 and will not operate at altitudes above 121 m, it is not necessary to have a valid airworthiness certificate, license, and aeronautical medical certificate; the insurance policy can be waived because the equipment belongs to a state-controlled institution (ANAC, 2021).

Results and Discussion

Currently, there are no methods or devices capable of altering, manipulating, or preventing the occurrence of weather phenomena such as atmospheric discharges, so it becomes necessary to apply techniques and measures to reduce the risks and damage generated by such conditions for both structures and equipment, as well as for people and animals present in the vicinity of the site, through the ADPS (ABNT, 2015).

According to Technical Procedure, Standard nº 27-2, structures and plants intended for grain storage and drying must present an approved and certified ADPS system by a qualified professional and maintain up-to-date documentation regarding maintenance and inspection (ABNT, 2015).

Taking into account the size and height of the structures, it is noted that numerous points for inspection work whose execution is framed as an activity at height both at the time of installation and during the inspections (ABNT, 2015).

Among the occurrences recorded in the pre-processing and storage stage, incidents involving falling structures in inspection and maintenance activities of cleaning machines, elevators, conveyors, and silos rank second in the highest frequency index, second only to accidents related to entrapment or engulfment (Bellochio & Coradi, 2022).

By identifying the necessary items to perform the external inspection of the ADPS using RPAS, a methodology was developed to perform the visual inspection of atmospheric discharge protection systems that addresses the general aspects and legal obligations on the part of the company.

It is observed that the use of unmanned aircraft has had unprecedented growth in a wide class of manufacturing, including mainly commercial and military. Most designers aim to perfect the aerodynamic operation of their design to provide greater payload, power, and range (Siddiqi & Lee, 2022).

Operations of this type consist of three elements: an unmanned aircraft, a ground control station, and a communication link between the two. Generally, the ground control station serves as a communication gateway with a real-time camera transmission display screen, which makes it possible to obtain data to assist and optimize numerous routine activities (Butcher et al., 2021).

To validate the methodology presented in this paper, ADPS inspection activities were performed with the aid of RPAS, following the steps in Figure 2.

Pre-inspection activities included steps such as: verifying and obtaining the necessary documentation for the operator and the RPAS; analyzing the weather conditions at the site; observing the structure to identify the presence of factors and/or elements that may generate obstructions in the process; and requesting flight on the SARPAS platform.

The risk analysis was carried out to describe the operational scenario found, listing the possible risks and their classification taking into account the probability and severity of occurrence, and presenting for each of the risks identified a mitigation solution based on the procedure for the preparation and use of operational risk assessment for unmanned aircraft operators.

Information was recorded, such as operator identification, aircraft, operational scenario, whether or not the operator should stay away from third party areas, whether or not the pilots need to undergo any specific training, and in case of an accident with injuries, what people to call and how to proceed.

During the evaluation, the following risks were identified: loss of the link (communication from the operator using the control with the aircraft), unfavorable weather conditions (rain and wind), and possibility of collision of the aircraft with cables (sustaining structures and with the power grid).

Using as an example situation 2 - unfavorable weather conditions (Table 2), the probability of occurrence was evaluated (4 - occasional: likely to occur a few times or historically has occurred infrequently), and the severity of the occurrence (D - small: minor incidents, damage to objects, animals or vegetation on the ground, minor injuries), data obtained through the Risk Matrix table probability, occurrence severity, and tolerability, of the Supplementary Instruction - IS no. 94-003.

With this information, the risk is framed in 4D, which according to the mentioned instruction, obtained moderate tolerability in which the operation can occur with preventive controls for risk mitigation established, which must be in place

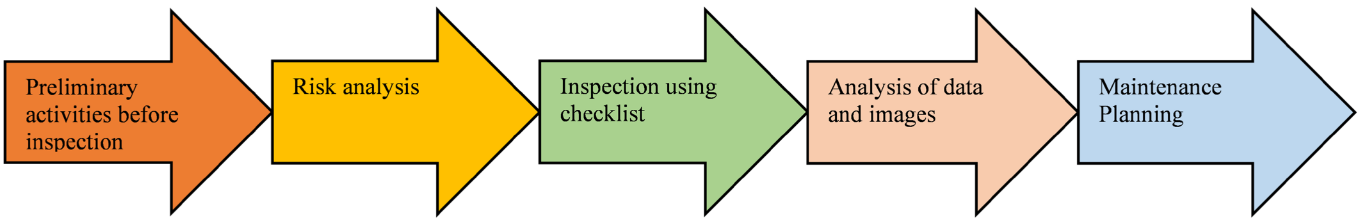

Figure 2. Scheme for inspection

Table 2. Risk assessment: link loss, unfavorable weather conditions, and aircraft collision with cables and power grid

Situation 1	Link Loss
Probability of occurrence	1
Severity of occurrence	E
Risk	1E
Tolerability	Very Low Risk
Hierarchy level of authorization of the operation	Responsible for the Unit being inspected.
Risk Mitigation Measures	The equipment should only be operated if the GPS system works and the Return-To-Home command is enabled. If a link loss occurs, the equipment will go up 50 m high and return to the take-off point.
Situation 2	**Unfavorable weather conditions**
Probability of occurrence	4
Severity of occurrence	D
Risk	4D
Tolerability	Moderate Risk
Hierarchy level of authorization of the operation	Responsible for the Unit being inspected.
Risk Mitigation Measures	The operation will be suspended in case of rain and carried out the following day. In strong gusts of wind, the operation can occur with preventive controls, and the operator is responsible for evaluating each situation (note: the equipment has sensors that alert the operator in case of risk).
Situation 3	**Collision with cables and electrical wiring**
Probability of occurrence	3
Severity of occurrence	C
Risk	3C
Tolerability	Moderate Risk
Hierarchy level of authorization of the operation	Responsible for the Unit being inspected.
Risk Mitigation Measures	The operation can occur with preventive controls to mitigate the established risk by identifying all cables and wiring and tracing a safe route to take pictures and images of the ADPS. The equipment has frontal sensors below the equipment.

Source: Adapted from ANAC (2021)

as needed. The next higher hierarchical level must approve operations at this level of risk.

This procedure was applied analogously to the other risks, for which the following mitigation procedures were established: for loss of link - the RPAS should be used with GPS, and the Return-To-Home command enabled; In case of unfavorable weather conditions, the operation must be suspended in case of rain or strong winds; and for collision with cables and electrical wiring a flight plan with a safe route has been drawn up, and the RPAS used must have frontal sensors.

Performing the ADPS inspection using the checklist and analyzing the data, it is worth noting that the catchment system can be composed of one or more combined protection methods, whose function is to conduct the atmospheric discharge current to earth safely. Among the existing ones, three stand out: the Protection Angle Method, also known as Franklin's Method; the Rolling Balls Method; and the Mesh or Faraday Cage Method (ABNT, 2015).

Developed by Benjamin Franklin and proven by Frenchman Thomas François D'Alibard in the year 1,752, the Angle of Protection method initially brought a grounded metal rod close to a storm cloud. It was possible to observe that the grounding cable conducted lightning when it hit the rod, thus establishing the initial principle for developing lightning rods (ABNT, 2015).

The inspection was performed on 11/28/2022 at 10:30 a.m. by real-time observation of the images captured by the equipment and recording for verification purposes (Figure 3A). It was observed that the ADPS was composed of two types of protection systems: Franklin Rod ADPS (Figure 3B) and Faraday Cage ADPS (Figure 3C), for which checklists were developed. At the time of the inspection, the pilot can note as an observation the identification of any observed situation, such as degradation or inconsistency in the ADPS system.

A.

B.

C.

Figure 3. Inspected storage and drying unit (A), Franklin rod ADPS, insulators, and cabling (B), and Faraday cage ADPS, insulators, and cabling (C)

After obtaining the media, they were evaluated by a qualified electrical engineer. The inspection of the Franklin Rod generated a score of 43.04, representing an alert level that required adjustments to be made (Figure 4).

Nº of evaluation: 01
Date: 11/28/22
Start time: 10:30

EVALUATION INDICATOR	SCORE
ALERT LEVEL (41 TO 50)	43.04

Company logo	CITY	COMPANY	CNPJ
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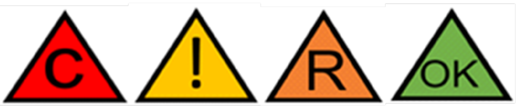
VISUAL INSPECTION OF ATMOSPHERIC DISCHARGE PROTECTION SYSTEMS (ADPS)

TYPE	REASON
■ Franklin rod	□ Suspicion of discharge
□ Faraday cage	□ Estrutural change
Obs:	□ Semester
	□ Annual
	□ Two years
	■ Others: Apply and validate methodology

	PROJECT	YES	NOT	NOT APPLICABLE	OTHER INFORMATION	POINT
1	Is the design up to date and correctly represents the installed ADPS?	□	■	□	The company does not have ADPS project, this item represents 30 points	0.00
	LIGTHININ ROD	YES	NOT	NOT APPLICABLE	OTHER INFORMATION	POINT
2	Do they have good fixation characteristics?	■	□	□		5.38
3	Are there no cracks or melting points?	■	□	□		5.38
4	Free of oxidation points, corrosion, or rust?	□	■	□	Presence of rust	0.00
5	Without the physical alterations (twisting, missing some component)?	□	■	□	Presence of loose cable in the rod and lack of signaling lamp	0.00
	DOWN SYSTEM (INSULATORS)	YES	NOT	NOT APPLICABLE	OTHER INFORMATION	POINT
6	Are the insulators properly fixed?	■	□	□		5.38
7	Are they exempt from any physical alteration?	■	□	□		5.38
8	No oxidation or corrosion points on the insulators?	■	□	□		5.38
9	Are the rubbers undamaged and not cracked?	■	□	□		5.38
	DOWN SYSTEM (CABLING)	YES	NOT	NOT APPLICABLE	OTHER INFORMATION	POINT
10	Are the cables not in contact with any part of the structure (except insulators)?	□	■	□	The cables are in contact with the guard, which was painted yellow	0.00
11	Are the cables well tensioned?	■	□	□		5.38
12	Are they free of dirt (putty, resins, paints) that could compromise the system?	□	■	□	The cables are in contact with the guard, which was painted yellow	0.00
13	Do the down conductors have no connections or splices?	□	■	□	Connections and amendments are observed in the descent cable	0.00
14	Are the connections or splices integral with no oxidation or corrosion points present?	■	□	□		5.38
	COMPLEMENTARY PROTECTION DEVICES	YES	NOT	NOT APPLICABLE	OTHER INFORMATION	POINT
15	Are there a complementary inspection device installed or procedures performed?*	□	■	□		0.00

TOTAL OF POINTS 43.04

CAPTION: EVALUATION INDICATOR



CRITIC LEVEL (0 A 40)	Proceed adjustments URGENT
ALERT LEVEL (41 A 50)	Schedule adjustments
REGULAR LEVEL (51 A 80)	In good condition, with restrictions to the norm
NORMAL LEVEL (81 A 104)	In good condition, with few or no restrictions to the norm

Responsible for inspection

* Complementary protection devices is equivalent to 4 points.

Description of the methodology used in the evaluation:

Inspection made with DJI Mavic Pro drone through photos and filming of the unit ADPS system. For the score, question 1 was considere weight 30 (project) and questions from 2 to 14 with an equal weight of 5.38 (70/13).

1

Figure 4. Franklin rod inspection

Maintenance planning: according to the inspection carried out on the Franklin Rod, Figure 4, the following adaptations need to be scheduled:

Question 1 - Project - Have the ADPS prepared and updated by a qualified professional; the company currently does not have the project because it is an old building;

Question 2 – Lightning rods - Replace the rusty ones, and connect and maintain the lighting system;

Question 3 - Drop system (cabling) - Adjust the cable so it doesn't touch the guardrail; check if it is a splice in the cable or just an insulation because the legislation forbids splices in drop cables, except at 1.5 m from the ground, where the test connector must be installed. It is important to note that this prohibition only applies to using cables as down conductors, i.e., it does not apply to the case of flat bars used as conductors (ABNT, 2015).

The same procedure was performed with the Faraday cage ADPS, Figure 3C, which generated a score of 70.0, a regular level, in good condition and with restriction to the norm, with the need for adequacy for not having the ADPS project.

The Faraday cage method consists of a long mesh of pickups spaced based on their radius of protection and is recommended for structures that have a large horizontal area, such as roofs and slabs, and can also be used as a means of protection for lateral discharges in structures over 60 m (ABNT, 2015).

Once the elements that require maintenance have been identified, it becomes possible to plan the process to direct the activities only to the points where they are really necessary, thus avoiding unnecessary exposure of the employee to the risks presented by working at height and also providing greater agility and predictability of the conditions in which the structure is found.

It is observed that RPAS can make processes faster and more agile, improving accuracy, safety, and cost-effectiveness, with the consequence of commercial use associated with vast economic opportunities, among which can be cited the inspection of ADPS and storage structures, analyzed in this research (Kitonsa & Kruglikov, 2018).

Among the advantages of using RPAS for the inspection of the ADPS system is the elimination of exposure to work performed at height, greater agility, easier access to hard-to-reach places, registration through photos and videos, real-time viewing of camera images, and ease in finding details and different angles of the same point, which can be used and analyzed later in the preparation of the report by the qualified professional.

The disadvantages are the dependence on weather conditions, obstacles, and cables used to support the structure that makes it difficult to operate the equipment (which can be overcome by the quality of the camera and zoom), lack of pilot experience, and high cost to obtain the RPAS (photography and filming can be outsourced).

In this research, activities related to the inspection of existing systems were addressed, however, it is possible to use the method during the analysis and preparation of the project, monitoring the installation of the ADPS system, after suspicion of atmospheric discharge and in the planning of maintenance activities when a worker needs to have access to the site, being used in prior risk analysis.

It was observed that several old buildings were not suitable for worker access during the inspection, not only making it difficult to access the site but also exposing the worker to the risk of falling, for not having many times the anchorage points, being necessary for some situations the use of elevating platforms that would increase the cost of the inspection, thus, the use of RPAS would be an alternative to overcome these difficulties.

Visual inspection must be performed every six months to identify and point out possible deteriorated points in the protection circuit. Annually, this inspection must be performed by a qualified professional, with the issuance of relevant documentation, for structures containing ammunition, explosives, or essential service providers or every three years for other structures (ABNT, 2015).

Due to its great mobility and the fact that it is not directly connected to wires and other devices that limit its reach, this equipment is a great ally in the performance of several activities linked to the most diverse areas. According to the systematic literature review performed, the areas that most use this type of technology can be observed:

a) In the scope of photovoltaic energy generation, the association of the use of Unmanned Aerial Vehicles - UAVs together with management and inspection techniques by infrared thermography has shown promise since proper maintenance increases efficiency and energy production and is an effective way to avoid, repair, or mitigate the effects of possible failures and degradation mechanisms (Ramírez et al., 2022).

Several studies have been developed on the use of RPAS in transmission line inspections, with a focus on the development and application of techniques for optimal route identification and autonomous insulator inspection, which provides greater agility to the process (Ma et al., 2021; Ahmed et al., 2022; Yin et al., 2022);

b) Civil construction - there are several reports, among them the application of deep learning methods associated with image capture techniques in the automation of defect evaluation due to moisture in structures, models for detecting and evaluating cracks in tanks, an inspection of pathological manifestations, and cracks in facades with ceramic cladding and investigation procedures for traditional wood structures (Jeong et al., 2020; Liu et al., 2020; Martinez et al., 2020; Wu et al., 2020);

c) Agriculture and other areas - in the agricultural sector, the use of RPAS has been gaining space in the performance of several activities, such as geomapping, pest control, and soil analysis, among other applications, mainly due to its operating characteristics, which allow the development of non-destructive analysis of the terrain in a shorter time. Tan et al. (2022) addressed in their research the combination of UAV (Unmanned Aerial Vehicle) technologies and machine learning algorithms to explore efficient ways to detect the three main growth stages of rice seedlings.

Parallel to the themes mentioned so far, some other applications present in the literature are worth mentioning: the use of photogrammetry products for semi-automatic detection and damage classification on roads affected by landslides; identifying flight parameters for detecting potholes in sidewalks; and crowd counting (Ribeiro et al., 2020; Romero-Chambi et al., 2020; Hou et al., 2021).

For future work, it is intended to identify the minimum characteristics necessary for the equipment to perform the ADPS inspection, such as the quality of the camera for image and video analysis; battery life; and which obstacle detection sensors are necessary.

Once the inspection methodology has been validated, the intention is to develop software to analyze the collected images and identify the non-conformities described in the evaluation checklist (broken cable, oxidation, among others), which will generate an evaluation report, with the respective score, which will help in planning maintenance and issuing the report by the qualified professional who, in many situations, will not need to go to the evaluated site. In each inspection, techniques can be used to identify ideal routes, elaborating a flight plan to carry out the autonomous inspection of the system, which provides greater agility and safety to the process.

Conclusions

1. Unmanned aerial vehicles are an excellent alternative for inspecting structures and planning activities at height.

2. The main advantage of using Remotely Piloted Aircraft System in work at height is related to eliminating exposure to fall risk and the disadvantage of dependence on favorable weather conditions.

3. The Atmospheric Discharge Protection Systems inspection using Remotely Piloted Aircraft System proved satisfactory through the photos and filming, helping the qualified professional issue the technical inspection report.

4. The evaluation methodology can be improved by using the autonomous inspection of the system that, together with the use of image and video analysis software, can identify the non-conformities.

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