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Inspection of Solar Photovoltaic Farms Using Drones

Methods

The inspection of solar fields is a tiring and tedious process when done by crews on foot. Each panel must be inspected physically which takes an excessive amount of time. Inspection by foot also is not a very reliable form of inspection. Many forms of problems are missed or over-looked during ground inspections. These problems with ground inspection led to the need for a more efficient form of inspection. Drones have become that new and more efficient form of inspection.

Prior to the introduction of drones into the solar photovoltaic field, a few other methods of inspection were experimented with. These methods are all ground-based inspections. The first method described will be the one camera tripod. This consists of one camera connected to a cherry picker to retrieve photos of the panels from above. Set up of the equipment is simple and does not take long. This method is flexible but is slow due to the single camera only being able to capture one to two panels at a time. The second ground level inspection is multi-camera tripod method. This method is larger, so takes more time and crew members to set up. The longer setup time is made up for with this method's quicker inspection time. Due to the greater number of cameras, this tripod method is capable of capturing more panels per shot. While these two methods are effective, they are simply not practical or efficient enough for large scale solar farms. This still left a need for a more appropriate form of inspection.

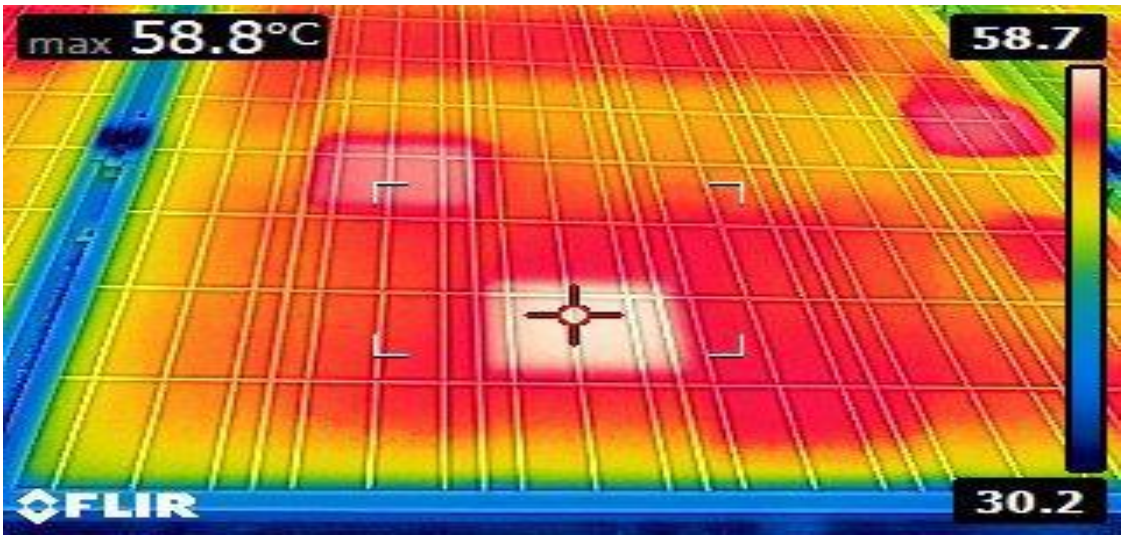
With inspections being conducted using aerial cameras, drones are inevitably the next step for solar field inspection. Drones offer a completely new, wide range of possibilities when it comes to inspection processes. Drones allow much quicker inspection times while increasing the quality of inspection. Drones only require one to two crew members and a small amount of time to setup, unlike the ground-based inspection methods. Drones are also more affordable than the alternatives. Drones are consistently being improved on and the price becomes more affordable.

(Figure 1) This photo shows a drone with an IR camera connected inspecting a group of solar panels. This particular PV farm is located on the top of a car garage. This image depicts just how versatile and easy to manage drones are. This further shows why drones are the most efficient inspection method. (Aghaei, 2014)

Camera Options

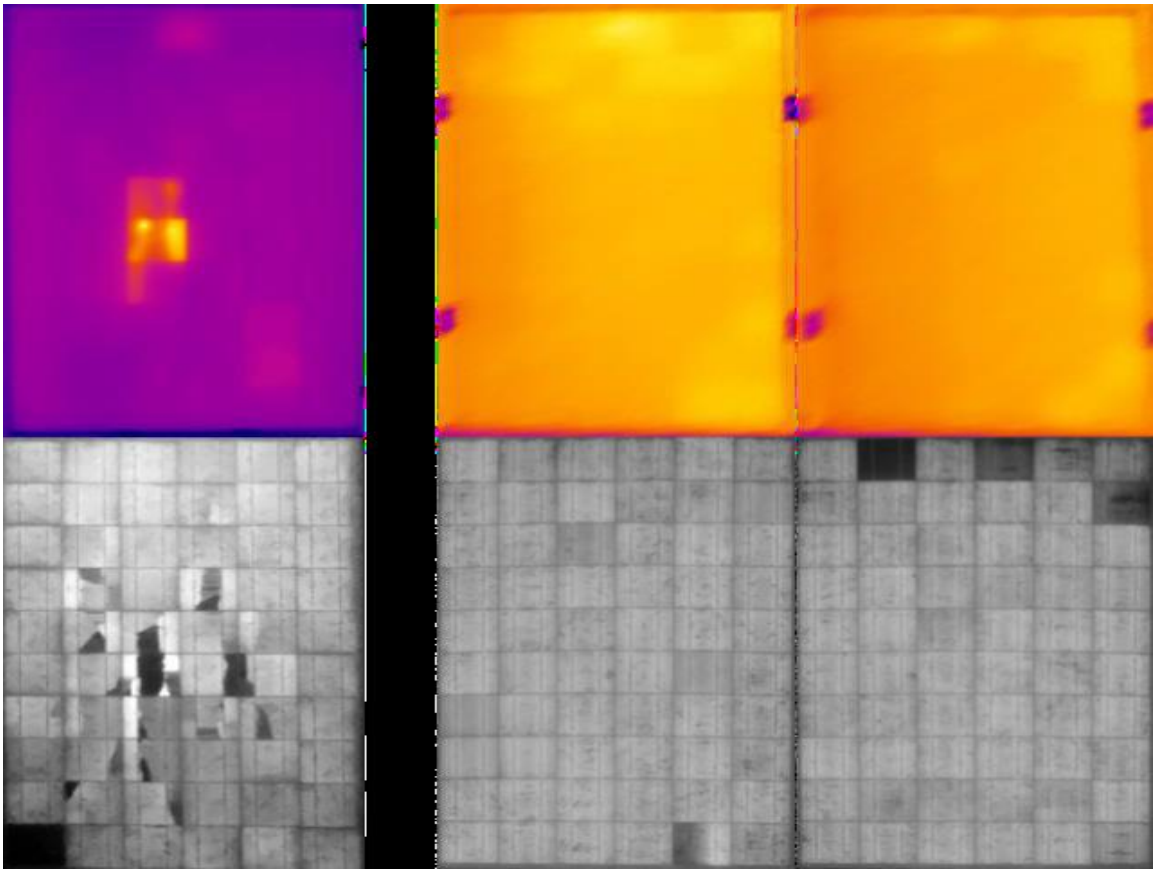
Drones inspect the solar panels using a camera secured to the drone. Different types of inspections are done depending on the type of camera used with the drone. Mutiple cameras and inspection forms exist with the use of drones, but there are two main inspection forms that are the most popular. There is a debate including these two inspection types involving the cameras and which is more efficient. Original inspections were done with Infrared imaging (IR). Now many inspectors are using electroluminescence imaging (EL), arguing that this form is more advanced and accurate.

IR inspection methods are done by taking aerial photographs of the solar panels and analyzing the temperature of the panels. Through the images it can be seen if the panels are becoming too hot it general, or if there are hot spots on the panel. Hot spots are the most recurrent defect on a panel and are easily seen through IR inspection. IR images are effective and make defects easy to detect. The color differences are a simple way to quickly examine a solar panel. While IR has some good aspects, there are also many downsides involving IR. The images provided from the camera are easily read but lack much detail. This means that certain defects, such as cracks, may be overlooked. This lack of detail also can cause an inspector to overlook a potential problem. IR also has a low resolution, which drastically limits the distance the drone can be from the panels themselves. IR images may also lead to an incorrect inspection of the panels due to the simplicity of the images. The simple color scheme can be easily misinterpreted resulting in an incorrect inspection. These inspections can also only be done during the day when the sun is shining, which is also a limitation of this inspection method.



(Figure 2) This image is a photo taken by an IR camera connected to a drone. In this image it can be observed that there are heat differences in the panel and hot spots. These hot spots are what lead to defects within the panel. (Leloux and Narvarte, 2015)

The second form of drone inspection, EL, is arguably more efficient and reliable than IR. This method involves using a certain electrical process to make the panels appear as if they are lit. This allows the camera to retrieve much more detailed images than provided with IR. These images give a much deeper look into the state of the panel. With EL many more defects are noticeable. Another advantage involved with this method is the capability of locating defects. With IR, problem areas are very broad. In EL images, defects are easily visible and can be traced to a precise spot on the panel. This is the greatest advantage for this method. This method also has some disadvantages. Due to the way this inspection works, inspections can only be conducted at night. EL also cannot observe hot spots in the way that IR may.



(Figure 3) This image shows a comparison between IR inspection images(top) and EL inspection images(bottom). Both images were taken by the respective camera connected to a drone. (Koch et al, 2016)

While some inspectors and researchers may side with either solely EL or IR, most believe a thorough and complete inspection cannot be done without involving both methods. Each method offers a different perspective of the panels that is valuable in its own way. With IR, the temperature and heat distribution of the panel is clearly displayed. This information is important, because the different temperatures of the panel are a direct display of how the panel is observing sunlight. If there are certain hot spots present this can lead to damage. Without IR this information would not be attainable. With EL, extremely in depth and detailed images are provided that allow a deeper inspection of the panel. EL allows micro-cracks and certain other defects visible. The precise location of defects is also available when using EL. Due to these different aspects of each method, it can be seen why a combination of both methods is most efficient. Some advancements have been made that allow photos from both methods to be combined to provide an ultimate look at each panel.

Drone Inspection Technology

As previously stated, cameras attached to the drones are used to inspect the solar fields. However, it is not as simple as it sounds. The drones themselves are quite complex machines. The drones used for inspection must have multiple rotors capable of flying at certain speeds and capable of hovering in place. The drone must be able to hover almost motionless to achieve the highest quality image possible. The drone must also be lightweight, so it is easily flyable. Weight must also be minimal to conserve battery power. However, the drone must be strong enough to

maintain the weight of camera and the cameras operating equipment. Batteries must also be included that can fly a certain amount of time to ensure a successful inspection period. With such strict criteria, drones are still produced daily for affordable prices and are constantly improving.

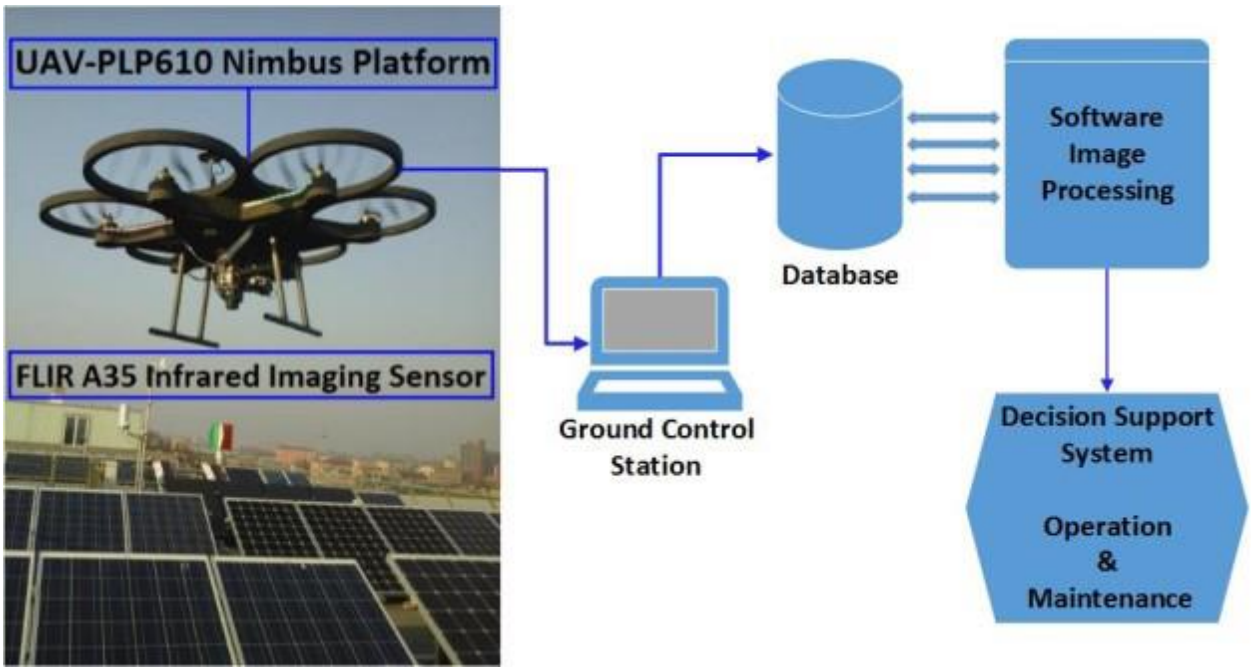
The drone is only half of the equation when it comes to the inspection process. A reliable camera and equipment must also be included to ensure a proper inspection. The camera will be chosen based on the inspection method, however the equipment securing the camera may vary. Camera mounts began as solid mounts capable of holding the camera at one angle securely. This means that to retrieve photos from different angles of the panel the drone must be repositioned. While this works, it is not as time effective as it could be. Repositioning the drone means the operator must move the drone, using battery power, and bring the drone to a stable hover once more. Mounts have now been developed that are capable of being remote controlled from the ground. These mounts allow the camera to be rotated to nearly any angle needed, allowing the drone to remain in its place hovering, while photos from multiple angles of the panels can be retrieved. The rotating mount in combination with the zoom of the camera allows for precise imaging of solar panels.

Depending on the process used to inspect, many other pieces of equipment many be attached to the drone. Some inspectors choose to include equipment on the drone that is capable of processing images. Equipment capable of retrieving other valuable information relating to the solar farm may also be included. Most inspection drones have a standard form of GPS connected to aid in the inspection process. The GPS coordinates of the drone can be paired with the photos taken to locate which panel is pictured in each photo. The exact coordinates delivered by the GPS make locating certain panels and defects much simpler.

Image Inspection Process

Through other aerial forms of inspection, photos are taken and the images are later reviewed and inspected for panel defects. This process can be long and tedious depending on the size of the panels and the size of the solar field itself. This requires a large amount of time to be set aside after inspection for a review of the captured images. Not only does this process take an excessive amount of time, it also can require a significant amount of people depending once again on the size of the solar field being inspected. This part of the inspection process is inconvenient. This post-inspection stage is also improved by using drones for inspection.

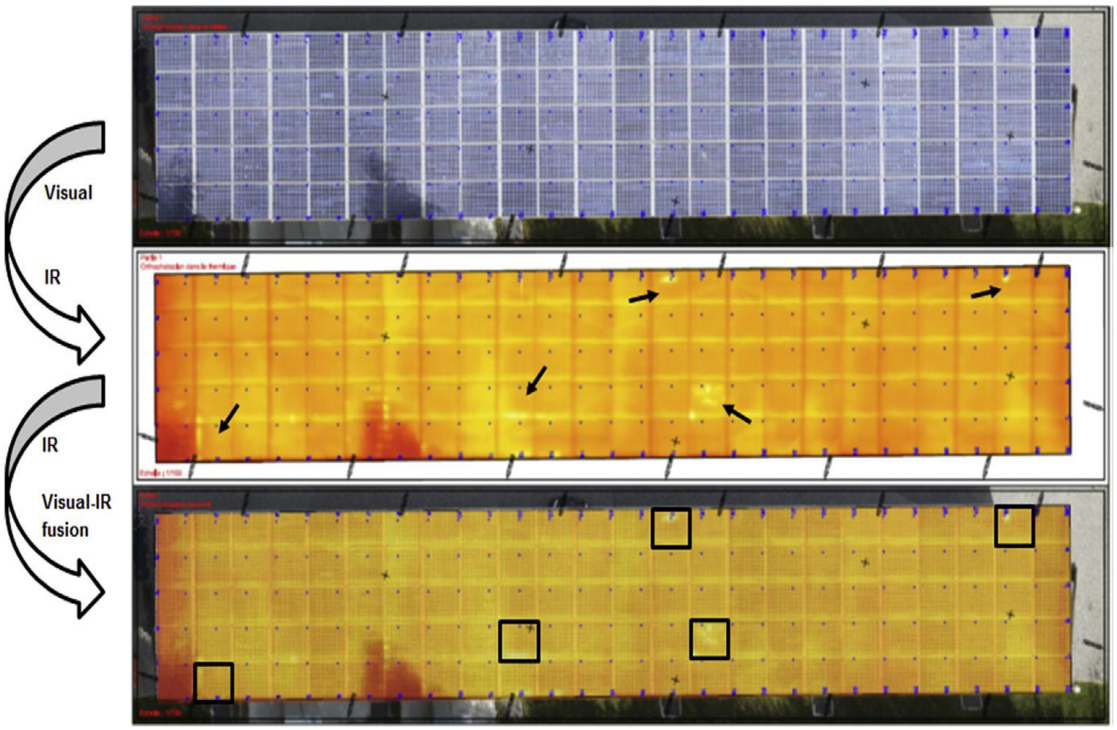
While other aerial forms of inspection require a period for review of the images by human, drones inspect and review simultaneously. While the drone is inspecting the panels, it sends the photos taken to a ground control station. When the pictures arrive at the ground control station they documented and sent to a database. After being saved at the database, the images are sent to a software that analyzes the images and the data withheld in them. This data is organized and arranged for easy decipher. This data is then sent to a decision support system that analyzes it and searches for defects. If a defect is noted, the system determines if the defect is significant enough to notify the panel inspectors. For noted defects, the location of these defects and potential solutions are given by the system.



(Figure 4) This image shows the process the photos are exposed to immediately after being taken by the drone. This process is done simultaneously with the drone inspection to drastically decrease the inspection and evaluation time. (Aghaei et al, 2015)

Current Times

The most recent inspections are being done with multiple drones, each with a different camera connected. These cameras being an IR camera, an EL camera, and a high-resolution camera that captures normal images. Each drone is equipped with a GPS with the same route set. The purpose of this process is to have an inspection that offers an in depth look that was before not possible. With these three different types of images, nearly all types of defects can be looked for. This ensures that each panel is operating appropriately. Some software systems have been invented that are capable of placing the inspection images from different cameras on top one another. This allows a layered view of the panel that revolutionizes the inspection process.



(Figure 5) This image shows the process of combining a normal high-resolution image with an IR image. This allows a layered look at the panels and makes identifying defects easier and far more efficient. (Tsanakas and Shakarchi, 2016)

Inspectors today are continually advancing the inspection process with drones being the center of attention. With drones the realm of possibility has no end. The inspection process is quicker and more efficient than it has ever been and will only continue to improve.

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