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Solar Panel Fault Detection

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Abstract: Thermal imaging offers several advantages in solar panel inspection. Faults can clearly be seen on a thermal image and Thermal infrared camera captures the raw thermal images of solar panels. These raw thermal images most likely to have many important entities which will help us to analyse solar panel image in detail. By capturing radiometric images of solar panel we will be able to explore these entities to inspect solar panels. Large areas of solar photovoltaic farms can be captured for scanning purpose using thermal imaging camera. In this work, we are focusing on potential problem areas on solar panel that can be detected and rectify before actual problem occurs. We have observed characteristics of solar panel and faults to detect various faults on solar panel leading to early fault detection and thus helping reduction in energy losses. This paper introduces most effective method for fault detection and location on solar panel.
Keywords: Solar Panels, Faults, Thermal Images, Radiometric Images, Electricity, Inspection

I. INTRODUCTION

The significance of photovoltaic (PV) systems is expanded over the past few years due to rapid growth of solar industry. Fault analysis in solar photovoltaic (PV) is an important task to increase its reliability, efficiency and safety in PV systems and, if not detected, may not only reduce electricity generation but also threatens the availability of the whole system.
Fault analysis is an important task to eliminate any kind of hazardous and undesirable situations arising in the operation of PV array. Solar panel fault detection methods are classified in

A. Visual Analysis (discoloration, browning, surface soiling and delamination)
B. Thermal Imaging
C. Electrical (dark/illuminated curve measurement, transmittance line diagnosis, RF measurement)

Here, the method used for fault detection is of thermography. It states that thermal images are captured using thermal camera which is mounted on unmanned Aerial Vehicle (UAV) system. The images are captured and then used for fault detection and location.
The main advantage of thermal image is that we can locate faults with naked eyes and identify which type of fault is present in the image. While capturing thermal images some rules and guidelines are needed to be followed such as angle with images are captured. Emissivity and reflection co-efficient of the camera and of object under inspection is also important. Earlier, inspection with thermal images usually take place manually, wherein: 1000's of thermal images where scanned manually and differentiated according to faulty and non-faulty ones. This process is time consuming and tedious. While scanning thermal images manually, many a times due to certain factors faults used to get ignored. As it is time consuming the maintenance of the solar panel gets delayed which directly affects the power generation of the plant.
This paper proposes a methodology which helps in automatic fault detection and location with at most accuracy. Once the thermal images are captured, they can be processed automatically and results are immediately available with the plant operator. This method not only saves the time required for fault identification but also helps in boosting the electricity generation of the power plant

II. TYPES AND CAUSES OF FAULTS

Different types of faults in solar panels are Hotspots, Diode Faults, String Faults, patchwork pattern. Hotspots are cells with elevated temperature as compared with other cells [2]. Diode faults are the faults where in one of the three or all of three diodes in solar panels are faulty. String faults occur when diode fault is left unattended. Patchwork pattern occurs when same cells has multiple temperature range which results in damaging of entire cell.
There are different reasons for faults to occur such as cell mismatch, shading, rooftop conditions, cell damage, soiling. Cell mismatch occurs when cells with different current capacity are connected in series [3]. Shading leads to jumping in of diode in order to bypass the excess negative voltage which leads to diode fault. Soiling occurs due to heavy winds and other climatic conditions which results in reduction in electricity generation of the power plant.

III. FAULT DETECTION METHODS

There are different methods available for fault detection on solar panels.

A. Temperature Extraction

As mentioned previously Faults in solar panels are the areas where temperature is maximum or greater as compared to other areas. In this case image area is considered to be as pixel. We will extract metadata from an image to find the pixel on which fault is present. Raw thermal data will give us temperature of each pixel.

The temperature extracted is in the form of excel file that helps in finding pixel co-ordinates of the faults. From the excel file we can find maximum temperature and locate co-ordinates onto the image [4].

Since the images captured were not according to the rules of thermography, this approach cannot give us accurate results. Bad thermography also resulted in 'Heat Island Effect' wherein the temperature of land and the temperature of faults is almost same or in some cases temperature of land is more than temperature of panel which is not desirable for fault detection. Also, the images were taken perpendicular which resulted in fisheye effect on the solar thermal images. Due to this we were not able to accurately separate out land & panel which resulted in data loss. So, the methodology used that gave us the accurate results is image segmentation.

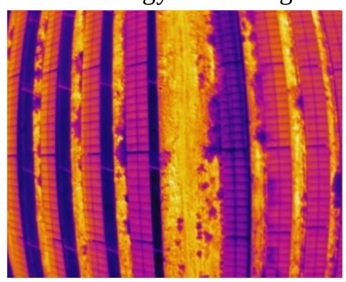

Fig. 1 Reflections in Thermal Image of Solar Panel

B. Image Segmentation

An image is set of different pixels. Pixels with similar attributes are grouped together for image segmentation. It created pixel wise mask for each object present in the image. There are different types of segmentation methods available such as semantic segmentation, threshold segmentation and instance segmentation. Threshold segmentation method is best suited for our images [5].

In this type of segmentation threshold value is set and pixels falling below or above that threshold can be classified accordingly. The thermal image is converted into grayscale image. The image is classified as foreground and background. The mean of the pixels is calculated and is used as a threshold. If the pixel value is more than the threshold, it will be treated as background either wise it is treated as foreground. The darker region represents back ground and brighter region represents foreground.

As, we have discussed earlier the properties of land and that of faults are similar hence even after segmentation they are similar. Now we can add a patch on all the values with low intensity our faults get detected along with land. Ideally from the image it is very clear to distinguish between land and panel so even if land gets detected it is easy to eliminate it while performing panel inspection.

Steps involved in fault identification using image segmentation.

1) *Step1:* Load the RGB Image & convert it in to gray
2) *Step2:* Apply Image Segmentation
3) *Step3:* Intensity Extraction of each pixel
4) *Step4:* locate lowest intensity pixel coordinates (black color)
5) *Step5:* Locate the faults on solar panel

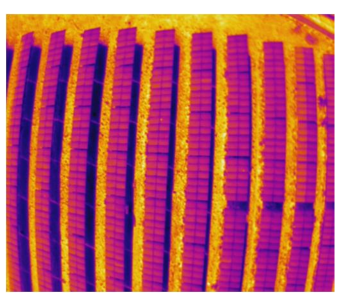

Fig. 2 RGB Thermal Image

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Fig. 3 Threshold Image

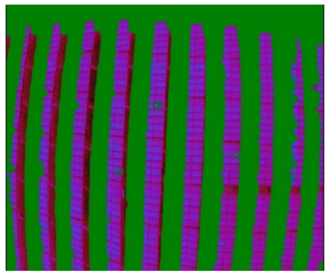

Fig. 4 Fault Detection

The above Fig.4 depicts accurate fault identification and location using image segmentation. Around 300-400 images were tested using image segmentation and we are able to accurately detect and locate faults on panel.

IV. CONCLUSIONS

Initially, we extracted metadata which includes temperature of each pixel which resulted in false detection as a result of reflections and heat island effect present in thermal images thereafter, image segmentation was used to differentiate between land and panel and then color intensity of each pixel was extracted and then the lowest intensity was plotted. This resulted in fault detection along with land detected. This will help in automatic detection and location of faults on solar panel resulting in well maintenance of the solar system thus, increasing the electricity generation. We can improve the fault detection accuracy by using suitable lens in thermal camera to get unambiguous temperature data extracted from thermal image. Wide angle and unwanted reflections in thermal images can be avoided by following rules and guidelines of thermography to get accurate temperature data and vanish the heat island effect.

V. ACKNOWLEDGMENT

All the solar panel thermal images being tested are provided by TATA POWER.

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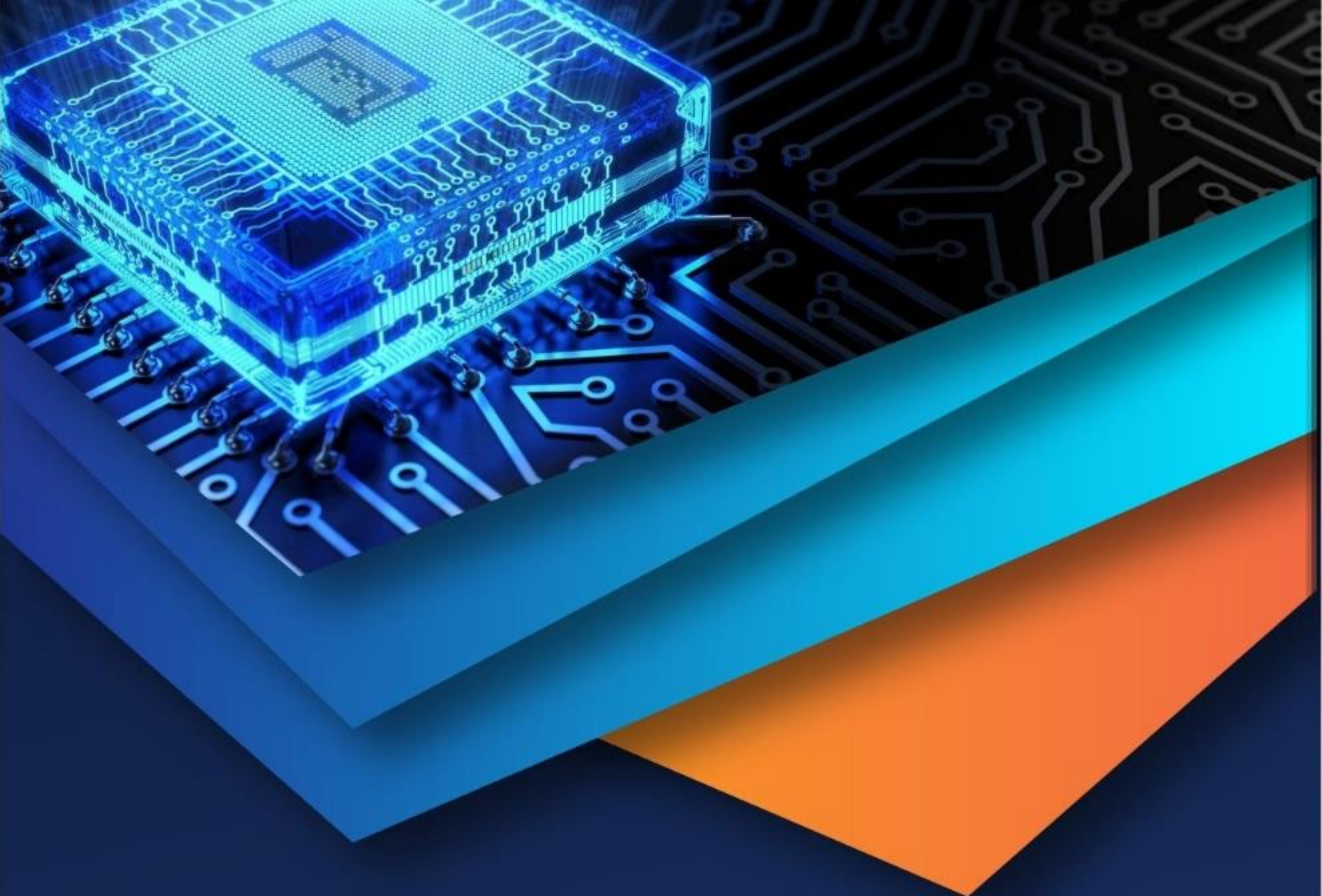

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