Detection of Defects in Solar Panels using Thermal Imaging by PCA and ICA Method

Farhan Ali Khan[1] Sanjay Singh[2]
[1]PG Student [2]Assistant Professor
[1]Department of Computer Science & Engineering [2]Department of Electronics & Communication Engineering
[1,2]HCST, Farah, Mathura, Uttar Pradesh, India

Abstract— For good efficiency, fast, reliable and smooth operation of any process we need a failure free operation. It gives a high production and also ensures high return on investments. A failure free operation is of fundamental importance for modern commercial solar power plants to achieve higher power generation efficiency and longer panel life. So a simple and reliable panel evaluation method is required to ensure that. By using thermal infrared imaging, glitches or defects in the solar panels can be easily detected without having to incorporate expensive electrical detection circuitry. In this paper, we propose a solar panel defect detection system based on thermal imaging, which automates the inspection process and mitigates the need for manual panel inspection in a large solar farm. So in this way solar panels can be checked while in operation without disturbing the continuity of operation. So it saves lot of time and cost of detection.

Key words: Solar Cell Imagining, Value Decomposition for Lower Band, CCD, Si-CCD, PCA (Principle Components Analysis), ICA (Independent Component Analysis)

I. Introduction

A. *Motivation and Background*

Identification of fault, its detection, protection and fault analysis are necessary to prevent unexpected events in solar photovoltaic (PV) systems. In spite of the fact that Solar PV systems have no moving parts and generally require low maintenance, they still have more number of chances to get various failures or faults along the PV arrays, PV modules, batteries, wiring, and power conditioning units and interconnections to utility. It is difficult to shut down PV modules completely during faults, since they are energized by sunlight in daytime. Also, PV is modular technology in which PV power plant can be made by connecting a large number of PV modules in series and parallel configuration. Once PV modules are electrically connected, any fault among them can affect the entire system performance. In a large PV solar module, it may be very difficult to properly identify or detect a fault. It can remain hidden in the PV system or unidentified until the whole system collapse or breaks down. In addition, the series and parallel combinations of solar PV arrays or solar PV modules for increasing the voltage and current capability also increases the magnitude of high short circuit current leading to various faults or dc arcs.

Several severe fire hazards have been reported in PV systems due to non-detection of fault. For example- Fig. 1.1(a) shows the fire hazard which took place in a 383 kW PV module in Bakersfield, California in 2009. Another fire hazard was occurred in a 1 MW PV power plant in Mount Holly, North Carolina, in 2011 shown in fig 1.1(b). In both these cases, the fault remained unnoticed and hidden within the system until the hazard caused catastrophic fire and shut down the system completely.

Fig. 1(a): fire hazard in a 383 kW PV array in Bakersfield, California in 2009

Fig. 1(b): fault occurred in 1 MW PV power plant in Mount Holly, North Carolina, in 2011

These fire hazards not only show the weakness in conventional fault detection and protection schemes in PV arrays, but also reveal the urgent need of a better way to prevent such issues.

II. Overview

There can be many defects in solar panels that can be developed due to manufacturing defect, cell damage, finger interruption, cracks and breaks developed due to handling and transportation or a part of solar panel in shadow which is not receiving a required amount of solar radiation to produce electricity thus creating hot spot. These defects need to be detected soon so that continuity and efficiency of operation is not affected. Previous method used for detection for defects used electroluminescence imaging method. In which electricity is given to solar panel which produces light in the electromagnetic spectrum. The solar module charged with electrical current will emit infrared light whose intensity will be darker for intrinsic crystal grain boundaries and extrinsic defects including micro-cracks, breaks and finger interruptions. The EL image can distinctly highlight the invisible defects but also create a random inhomogeneous background, which makes the inspection task extremely difficult.

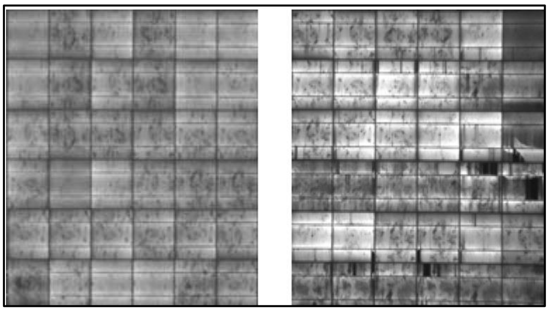

Fig. 2: EL images of (a) defect-free solar module, and (b) defective solar module.

In the EL imaging system, current is passed through a solar module in a darkened room, and then a cooled Si-CCD camera is used to capture the infrared light emitting from the excited solar module. Crystal silicon area with higher conversion efficiency gives brighter luminescence in the sensed image. The defects in the module such as micro-cracks, Breaks and finger interruptions will emerge as dark regions because they are not active and hardly emit light.

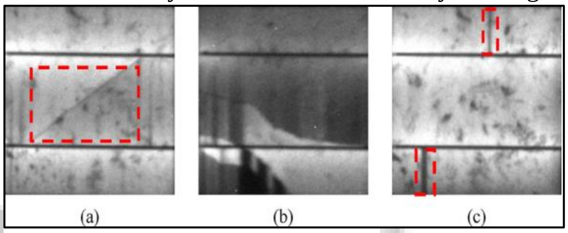

Fig. 3: Defect types of solar cells displayed in the EL image: (a) micro-crack (b) break (c) finger interruption.

Hence, it is necessary to develop more responsive fault-detection algorithms that can make better use of these readily available PV data. One of the effective techniques to detect and identify the fault instant is thermal imaging method based on PCA and ICA method to clearly detect the fault location or to classify the images as defected or not defected.

A. *Thermal Imaging*

An infrared thermal imaging deal with producing images of objects based on invisible infrared energy. Infrared energy is part of the electromagnetic spectrum, which we observe as heat and is invisible to the naked eye. Thermal imaging uses Thermographic camera for producing the infrared image of the object. Similar to ordinary common camera that forms a image of a object using visible light. Instead of the 400–700 nanometre range of the visible light camera, infrared cameras operate in wavelengths as long as 14,000 nm (14 µm). Some amount of thermal energy is emitted from all living, objects, and materials. Infrared technology can be extensively used to capture this energy and represent it in the form of a thermo gram which can be perceived as images. Also one of the features of Thermal imaging is that it can successfully penetrate such environments as smoke, light fog, snow, rain and extreme darkness.

III. METHODOLOGY

To identifying the presence or absence of defects in a solar cell sub image we consider two approaches. Our method used the first approach which is based on feature extraction and the second approach is based on the image reconstruction from ICA basis images. We use these two approaches due to the reason that EL imaging system was not able to differentiate between dark region and the defected region in the images. The first ICA approach uses the feature vector as the linear combination of basis images. It is then compared with that of each training sample in the data set by a distance measure, and the minimum distance among all training samples is used as the discrimination measure. The second ICA approach is based on simply calculating the reconstruction error between the original solar cell sub image under inspection and its reconstructed image from the basis images. If the distance measured or reconstruction error find, is greater than a fixed threshold, it is recognized as a defective solar cell sub-image. Otherwise, it is stated as a defect-free sub-image. Or in other words The method makes use of first taking the infrared image of normal solar panel and then taking the infrared image of testing solar panel i.e defected solar panel by use of thermal imaging camera. Then the method use Independent Component Analysis (ICA) for feature extraction from the non-overlapping sub-windows of texture images and classifies a sub-window as defective or non-defective according to Euclidean distance between the feature obtained from average value of the features of a defect free sample and the feature obtained from one sub-window of a test image

IV. RESULT

The following results have been obtained from thermal imaging of solar panel.

Figure (a) shows a defected input image of a solar panel

Figure (b) shows a infrared image of a that solar panel by using thermal imaging

Figure (c) shows the actual position of defects found in solar panel by using the Principle Component Analysis (PCA) and Independent Component Analysis (ICA).

Fig. 4(a): defected input image

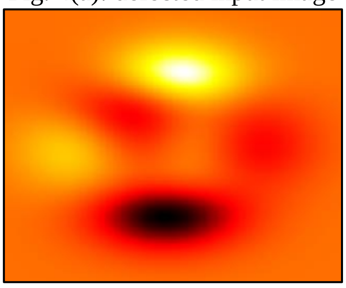

Fig. 4(b): thermal image of input Defected image

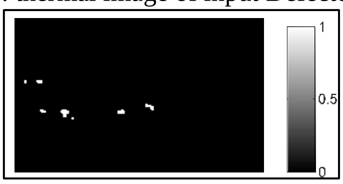

Fig. 4(c): Actual position of defects in defected solar panel

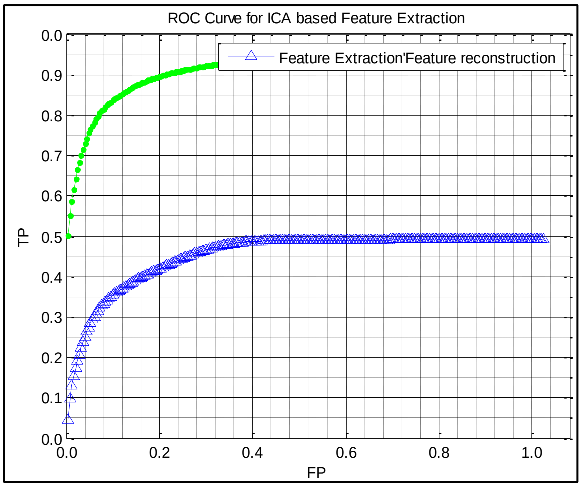

Fig. 5: A ROC curve for ICA based feature extraction over FP and TP

V. CONCLUSION AND FUTURE SCOPE

By doing thermal image processing of defected solar panel and analysis we have found actual location of faults and number of faults in the solar panels. i.e. the faults due to local hot spot or blind spot or break or crack due to fault. Previous methods used were not able to discriminate between dark regions and defected regions. So many a times fault remains unnoticed in the system which cause serious hazards to the PV systems. This method clearly distinguishes between normal region and defected region. So it is very efficient and time saving approach for testing the solar panels. It gives me a relatively quick result and gives with reliability. I have used MATLAB As software and image processing as a technique to compare two images. PCA and ICA method I have used for feature extraction of the image and image reconstruction to classify the images as defected or not defected. So it saves time and reliable compare to other conventional method of testing of solar panel. It will definitely help in future to examine the solar panel in less time with lots of cost saving and with reliability.

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