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Review on the Thermographic analysis of PV panels/system using the infrared thermal cameras

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Abstract - ***PV systems use a collection of PV panels to convert sunlight into electrical energy using the photoelectric effect. Each panel is made up of a few PV modules, which in turn consist of a matrix of PV cells that convert the solar irradiance into electricity. The failure of any PV cell may lead to a drop in power generation causing output yield losses. When a cell is shaded or not working, the cell consumes power from the adjacent series of solar cells instead of generating power. On solar farms, consisting of up to a few thousand PV panels, electrical testing at each individual PV panel is time consuming and cumbersome. This paper looks at the use of thermal imaging as a method for identification of faulty PV cells.***

Key Words: *Thermal Cameras, Grid, Hotspots, bypass diodes.*

1. Introduction

Quality assurance is of fundamental importance for solar panels. The failure-free operation of the panels is a prerequisite for efficient power generation, long life, and a high return on the investment. To ensure this failure free operation a fast, simple and reliable method to evaluate a solar panel's performance is required, both during the production process and after the panel has been installed. The use of thermal imaging cameras for solar panel evaluation offers several advantages.

Infrared thermography is a preventive, troubleshooting and predictive maintenance tool. In the hands of a thermographer an infrared camera can be used to make the world that is invisible to the naked human eye. Among different condition monitoring methods and non-destructive testing techniques available, infrared (IR) thermography is seen as a promising technique for fast, reliable inspection and defect detection. Infrared (IR) thermography is a two-dimensional non-destructive technique that utilizes the radiation in the infrared range of the electromagnetic spectrum (approximately 0.9– 14 μm) to produce images of a specific temperature pattern. According to the Planck's black body radiation law, infrared radiation is emitted by all objects and it is proportional to their temperatures. Hence, IR thermography makes it possible to determine the surface temperature and, consequently, any abnormalities to the temperature pattern of the inspected equipment. This information, together with data on the physical construction of the component and the thermodynamic state of the equipment is used to evaluate the degree of deterioration.

Thermodynamic model aspects

The performance analysis of a PV module can also be viewed by an energetic angle. Two major components contribute to a PV module energy performance, electrical and thermal energy. While solar radiation generates electricity (electrical energy) due to photovoltaic effect, solar cells are also heated due to heat dissipation mechanisms.

These energy components are completely competitive. While the electrical energy (electricity) can be used for useful purpose, the thermal energy is not utilized and lost to the ambient. However these thermal losses can be used in photovoltaic thermal (PV/T) modules or combined systems. Figure 1 presents a schematic drawing of a PV panel which is considered as a multi-layer thermodynamic wall. A PV panel is composed of a thick sheet of chemically hardened glass (3 mm), two very thin films of EVA foil (0.25 mm each), the Si-cell matrix (0.5 mm), and the back cover. If the EVA foils, the sealing materials and the frame, are supposed negligible, due to a low surface area, then the PV is composed of three main layers as figure shows.

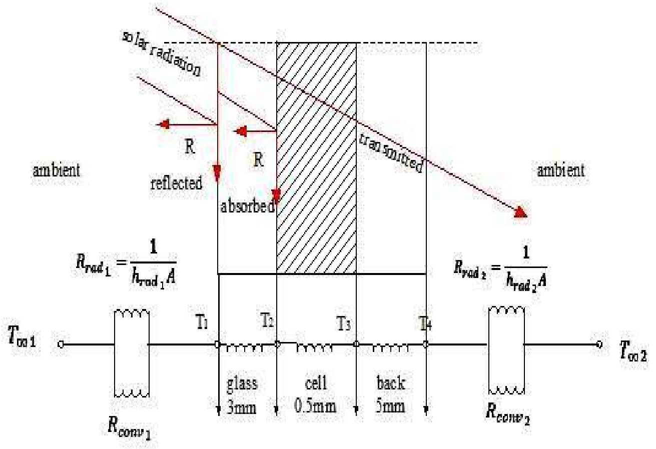

Fig.1 thermodynamic model of PV panel

Generally speaking, convection and radiation heat transfer (Q& from the front to the back surfaces of the module are considered significant. The energy balance equation for solar cell of a PV module can be written as eq. (1) shows, if is assumed that one dimensional heat mechanism is a fair approximation, the glass cover is at uniform temperature, the system is in quasi-steady state and the ohmic losses in the cell and module are negligible:

E&n = Q&Tca + Q&Tcbs + E&e 1

where :

E&n : the rate of solar energy available of PV module

Q&Tca : an overall heat loss from top surface of cell to ambient

Q&Tcbs : an overall heat transfer from cell to back surface

E&e : the rate of electrical energy produced.

An expression for temperature dependence electrical (energy) efficiency of a PV module can be given by:

n = no [1 − 0.0045(Tc −Ta)] 2a

the electrical efficiency in terms of energy is:

Ψe=ncell[1-0.0045(Tcell-25°C)] 2b

Where:

n : the PV module energy efficiency (%)

no : the electrical efficiency under standard test condition (solar radiation flux GT =1000 W/m², Ta =25 °C, wind velocity V f ≈1 m/s)

Ψe : the electrical efficiency (%)

ncell : the solar cell efficiency (%)

Tcell : the photovoltaic cell temp.

From the equation it is evident that the electrical or in energy term of total energy efficiency of a PV module is heavily induced by the thermal energy diffused due to solar radiation. If it is assumed that the cell temperature is approximately equal to the module temperature (Tcell ≈ Tmodule) then the knowledge of the latter will help estimating the module efficiency. The thermography approach emerges as a unique tool for the measuring of the module's surface temperature.

1.1 Thermography

Thermography is a method of inspecting electrical and mechanical equipment by obtaining heat distribution pictures. This inspection method is based on the fact that most components in a system indicate an increase in temperature when malfunctioning. The increase in temperature in an electrical circuit could be due to loose connections or a worn bearing in the case of mechanical equipment. By observing the heat patterns in operational system components, faults can be located and their seriousness evaluated [2].

The inspection tool used by Thermographer's is the Thermal Imager. These are sophisticated devices which measure the natural emissions of infrared radiation from a heated object and produce a thermal picture. Modern Thermal Imagers are portable with easily operated controls. As physical contact with the system is not required, inspections can be made under full operational conditions resulting in no loss of production or downtime.

Solar systems are outdoor electrical installations exposed to stresses of wind, rain, snow, melt and freeze cycles, and UV radiation. Such exposure can result in weathering and accelerated corrosion [1].

Thermal Infrared Camera a tool for Thermographic analysis

Thermal camera being the basic requirement of thermography through which the anomalies can clearly be seen on a crisp or fine thermal image and - unlike most other methods - thermal cameras can be used to scan installed solar panels during normal operation. Finally, thermal cameras also allow to scan large areas within a short time frame. In the field of research and development (R&D) thermal imaging cameras are already an established tool for the evaluation of solar cells and panels. For these sophisticated measurements, usually high performance cameras with cooled detectors are used under controlled laboratory conditions.

However, the use of thermal imaging cameras for solar panel evaluation is not restricted to the field of research. Un-cooled thermal imaging cameras are currently being used more and more for solar panel quality controls before installation and regular predictive maintenance checkups after the panel has been installed. Because these affordable cameras are handheld and lightweight, they allow a very flexible use in the field[4].

With a thermal imaging camera, potential problem areas can be detected and repaired before actual problems or failures occur. But not every thermal imaging camera is suited for solar cell inspection, and there are some rules and guidelines that need to be followed in order to perform efficient inspections and to ensure that you draw correct conclusions. However, the rules and guidelines are also applicable to the thermographic inspection of thin-film modules, as the basic concepts of thermography are the same.

A thermal camera will point you to:

- Corroded contacts or connectors
- Inverter issues
- Loose contacts
- Overheated connection points

What type of camera do you need?

Handheld thermal imaging cameras for predictive maintenance inspections typically have an uncooled microbolometer detector sensitive in the 8–14 μm waveband. However, glass is not transparent in this region. When solar cells are inspected from the front, a thermal imaging camera sees the heat distribution on the glass surface but only indirectly the heat distribution in the underlying cells. Therefore, the temperature differences that can be measured and seen on the solar panel's glass surface are small. In order for these differences to be visible, the thermal imaging camera used for these inspections needs a thermal sensitivity $\leq$0.08K. To clearly visualize small temperature differences in the thermal image, the camera should also allow manual adjustment of the level and span.

Photovoltaic modules are generally mounted on highly reflective aluminum framework, which shows up as a cold area on the thermal image, because it reflects the thermal radiation emitted by the sky. In practice that means that the thermal imaging camera will record the framework temperature as being well below 0°C. Because the thermal imaging camera's histogram equalization automatically adapts to the maximum and minimum measured temperatures, many small thermal anomalies will not immediately be visible. To achieve a high contrast thermal image continuous manual correction of the level and span would be needed.

Image analysis

The shape and location of hotspots on the thermal image will indicate a variety of faults. If an entire module is warmer than usual interconnection problems should be suspected. When individual cells or strings of cells are abnormally hot or shown as a warmer patchwork pattern, the cause can usually be found either in defective bypass diodes, internal short circuits or a cell mismatch. Shadowing and cracks in cells are evidenced by hotspots or polygonal patches in the thermal image. And the temperature rise of a cell or of part of a cell may indicate a defective cell or shadowing [6].

Thermal images obtained under load, no-load and short circuit condition should be compared. And if the front and rear faces of the module have been both inspected, these should be associated too, although temperatures obtained from the back may be higher as the cell is not covered by a glass surface. It should also be emphasized that classification and assessment of the thermal anomalies require a sound understanding of solar technology, the system under inspection and additional electrical measurements.

Identifying Hotspots

Many of the problems found on photovoltaic solar panels have to do with one important issue; hot spot heating. Hot spot heating can occur on a photovoltaic panel because of cell failure, interconnection failure, partial shading, and by having mismatched cells. When these problems occur a cell in a string of cells becomes negatively biased and instead of producing electrical energy it produces heat energy. This happens because that cells current is lower than those in the string[5].

As the PV modules have negative temperature coefficient for the maximum power, the increase of the temperature reduces power output. This heat makes thermography scanning an effective test method for detecting solar cells that are overheating and for identifying other anomalies that could cause a PV module to fail. Figure 2 show hotspots detected on overheated solar module cells using the infrared cameras [4].

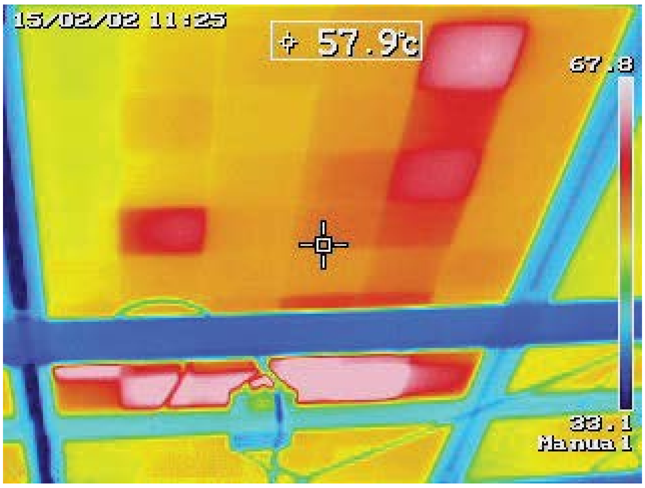

Fig.2 Hotspots identified by the thermal camera

To minimize hotspots produced by shade (the shading effect), manufacturers normally install bypass diodes in the solar panels. However, bypass diodes can degrade or become defective, leading to overheating issues. If the affected cells continue to heat up the adjacent cells, the power generated will be greatly reduced.

The solar panel hotspots create two issues:

• Fall in overall power production since cells consume power instead of producing.

• Power consumption continues to heat up cells and affect the production of neighboring cells.

Conclusion

Hot spots are detected, without externally visible damage on the panel surface. Thus, the problem must be attributed to internal causes, corrosion being one possible candidate. Invisible hot spots corresponding to areas where the internal structure of the panels is beginning to decay is visible with an IR camera help.

Grown-in or structural defects in electronic materials as well as electronic discharges or conducting particles are possible reasons of unwanted leakage in electronic devices. These currents may result in a decrease of the efficiency for a produced assembly or, even, in its complete failure. A thing that is good to be remarked is that some spots are by their nature invisible to the naked eye, contrary to the dust deposits, but with the infrared equipment even these ones can be seen and problems be removed as quickly as possible.

REFERENCES

[1] Solar Panel Thermography a basic guide, Testo Publications.

[2] A basic guide to thermography www.landinst.com

[3] P. Prabu, Jebaraj Sargunam, "Power Quality Improvement Using Solar Based Grid Interfacing Inverter," International Journal of Engineering Research & Technology (IJERT) Vol. 2 Issue 10, October – 2013

[4] Thermography for the photovoltaic panels using thermal imager, "Keysight Technologies".

[5] Harley Denio II, Level III Thermographer, Oregon Infrared LLC "Aerial Solar Thermography and Condition Monitoring of Photovoltaic Systems".

[6] "Identification of Solar Cell Defects using Thermal Imaging Techniques", www.iriss.com

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