Fault Detection Techniques and Analysis of Solar Cells and PV Modules: A Review

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Abstract: Photovoltaic market grew rapidly in a few years. One of the main reasons for the rapid growth of the photovoltaic industry is to reduce the cost of photovoltaic production. In this paper, we are discussing about the photovoltaic system along with the PV module. Also the faults occur in the solar panel named as Micro cracks, snail cracks and hotspot are discussed. Hotspot is positioned due to the overloading and thus PV array become hot. Micro-cracks do not necessarily result in direct production losses, but they can grow over time, for example, due to thermal stress or by seasonal and weather conditions. Larger micro cracks can damage the solar cell, which can lead to production losses. Snail trails are discoloration of panels that usually appear only after a few years of production. There are many reasons for snail trails, but one reason can be attributed to the use of defective front side metalized silver pastes in the solar cell manufacturing process.

Keywords: PV array system, Micro cracks, snail tracks, hotspot.

I. Introduction

Today's, due to development in energy cost, utilization of renewable energy resources such as solar energy is growing quickly. They are not restricted to a particular user. Preferably solar energy is, now, related to the power grid to match the power requirement. The Solar System security has perpetually been an essential issue. PV security has attained highest concentration as the performance of Solar PV modules are growing quickly. A novel solar panel does not contain critical faults as they progress through quality control investigation. But throughout its working life faults are coming in the system. As the time pass the fault severity increases [1].

1.1 Photovoltaic system

The PV system is used to transfer electrical energy to the destination by transferring the solar energy by photovoltaic effect and its structure. The PV module is the main block of the solar cell in which the PV modules are arranged in the form of array so that the production of electricity can be increased. The configuration of PV module is shown in figure below.

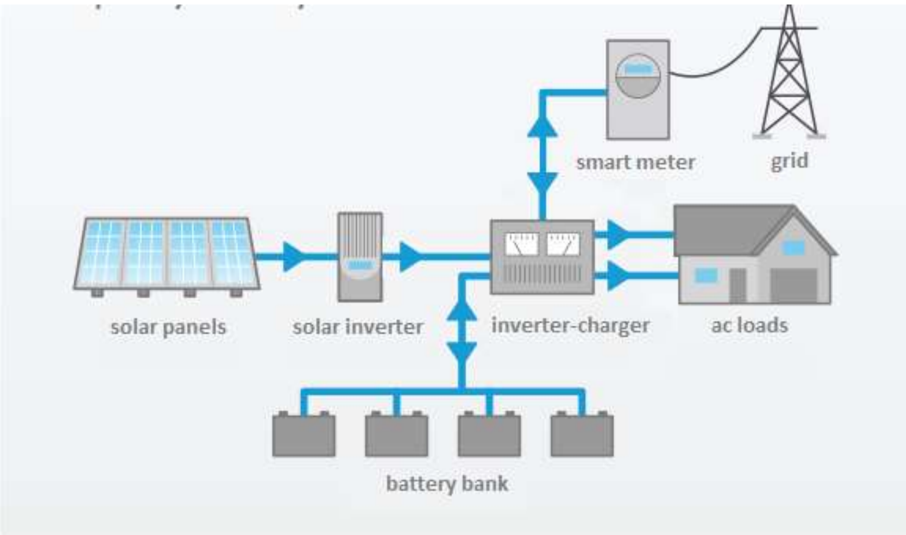

Figure1: PV system

In this type of a system, the production of solar system is linked to the AC side of the PV system. The Direct current (DC) produced by the solar PV array is initially passes through the battery less inverter that converts DC to AC (Alternating current).This is utilized by the AC loads during the AC load panel. Any additional current can be transmitted to the grid or saved in the battery after AC- DC translation by the inverter[2].

1.1.1 PV module

The PV Array block implements an array of photovoltaic (PV) modules. The array is built of strings of modules connected in parallel, each string consisting of modules connected in series [9].

The PV Array block is a five parameter model using a current source I_L (light-generated current), diode current (I_d), series resistance Rs, and shunt resistance Rsh to represent the irradiance- and temperature-dependent I-V characteristics of the modules[3].

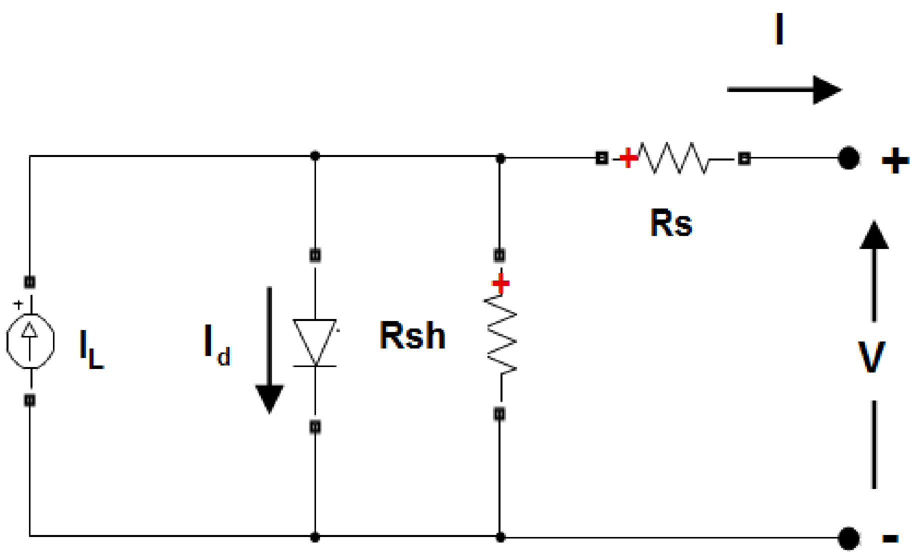

Figure 2 Photo voltic model

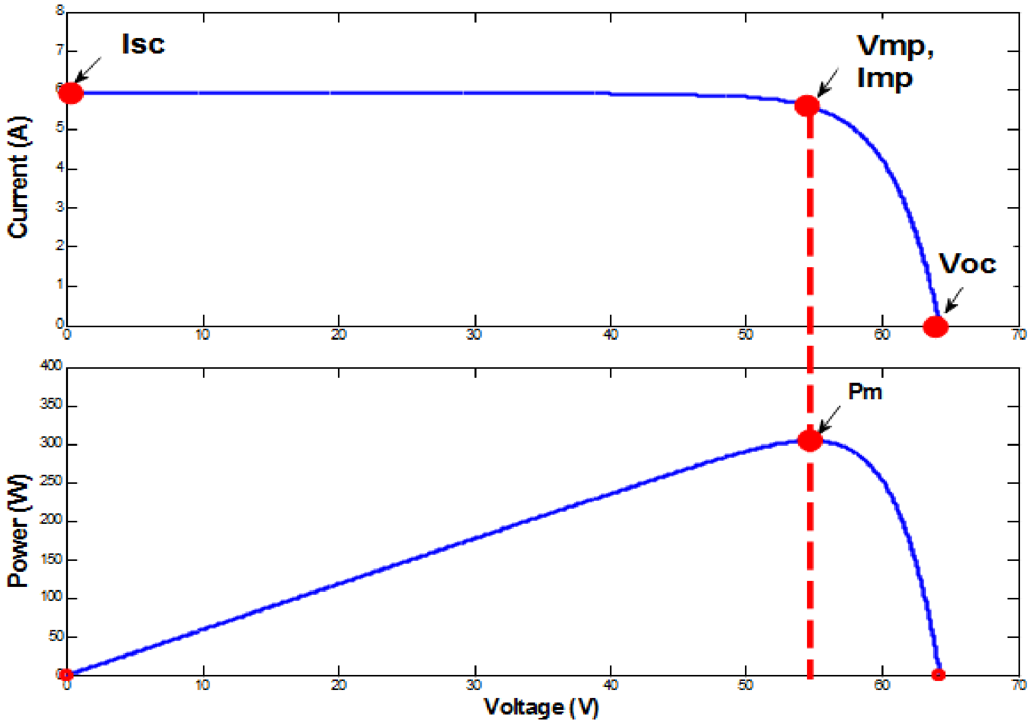

Figure 3 Waveform of current and power w.r.t Voltage

The V-I characteristics of diode for a single module are defined by the equation defined below [11].

$$I_d = I_0(\exp\left(\frac{v_d}{v_t}\right) - 1$$

$$v_t = \frac{Kt}{q} \times nI \times Ncell$$

Here $I_d \rightarrow Diode\ current\ in\ Ampere\ (A)$

$$V_d - \ Diode\ voltage$$

$$I_0 - Diode\ saturation\ current$$

Nl- diode ideality factor and nearly equal to 1

K –Boltzmann constant

q-Charge on electron

t -Cell temperature

Ncell- number of cells connected in series in the module

1.2 FAULTS IN SOLAR CELL

Mainly three kinds of faults are exist in the solar cell named as Micro Cracks, Snail Tracks, and Hotspot. A detail description of these faults is explained below:

1.2.1 MICRO cracks

- The solar cell is made up of silicon material which is very thin made up of 180 to 200 microns.
- Solar panels extend and shrink due to the process of thermic cycling.

- Solar panel extends in the sunny time because of high temperature
- Small defects in the silicon cell may lead to generous micro cracks due to thermic cycling
- Throughout this thermic cycling course, micro cracks may introduce in the solar panel.
- Microcracks defeat prevailing paths and could produce electrical conduction to fall off.
- This has a negative influence on the production and lifetime of the solar collection
- Performance disgrace due to micro cracks is unusually unambiguous in the commissioning – disgrace gives up after system has been in process for a year or longer
- Micro cracked modules will typically flash test within spec[4]

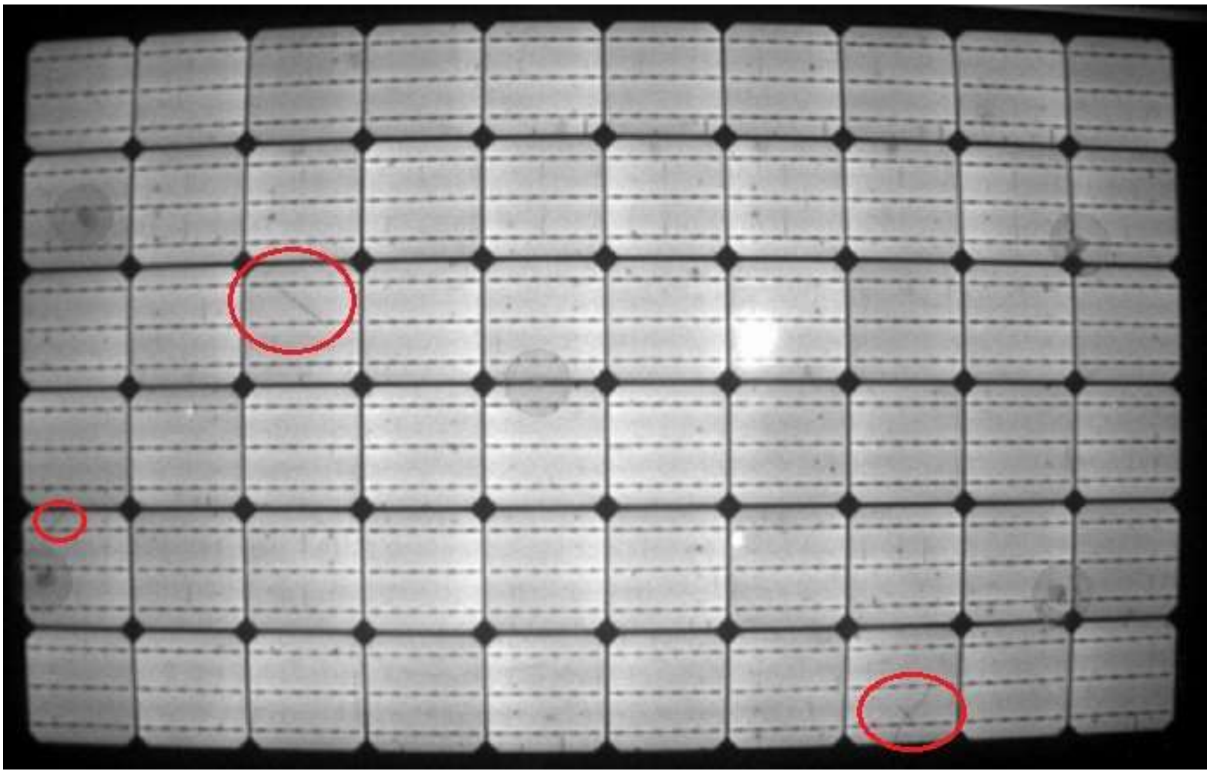

Figure 4: Causes of micro cracks

Microcracks can occurs due to the factors listed below

- During Manufacturing
- During Storage/Shipment and Transportation
- During Installation

1.2.2 Snail tracks

Figure5: Snail track

Snail track means the colours lines appears on the PV module. These tracks are formed by the snail or the worm as shown in figure above. These lines will affect the PV module. In few cases, the tracks curve downwards along the zig-zag of the cells, leaving some cell debris, while in other cases they cross the cells parallel to the busbars. In addition, this discoloration is also observed at the battery edges and busbars, in these cases referred to as "frame" and "fingerprint", respectively [5].

1.2.3 Hotspot

In general, hot spots are the most prominent when cells are placed in reverse bias. For example, consider the c-Si module shown below. Suppose a cell (marked in red) is shaded and all other cells are completely illuminated. Causes of shadows may include: Birds or leaves , Dirt or snow , Building shadows ... etc Shadow cells with small defects will be easy To withstand high reverse bias (~ 10-12 volts, Typical) until shadows are removed, However, batteries with significant shunt leaks in the opposite direction Currently and show extremely localized heating in Every defect. The temperature rise near the defect can be different from that Moderate (1-80 ° C) to extreme (> 200 ° C), however In a few seconds to achieve balance[6].

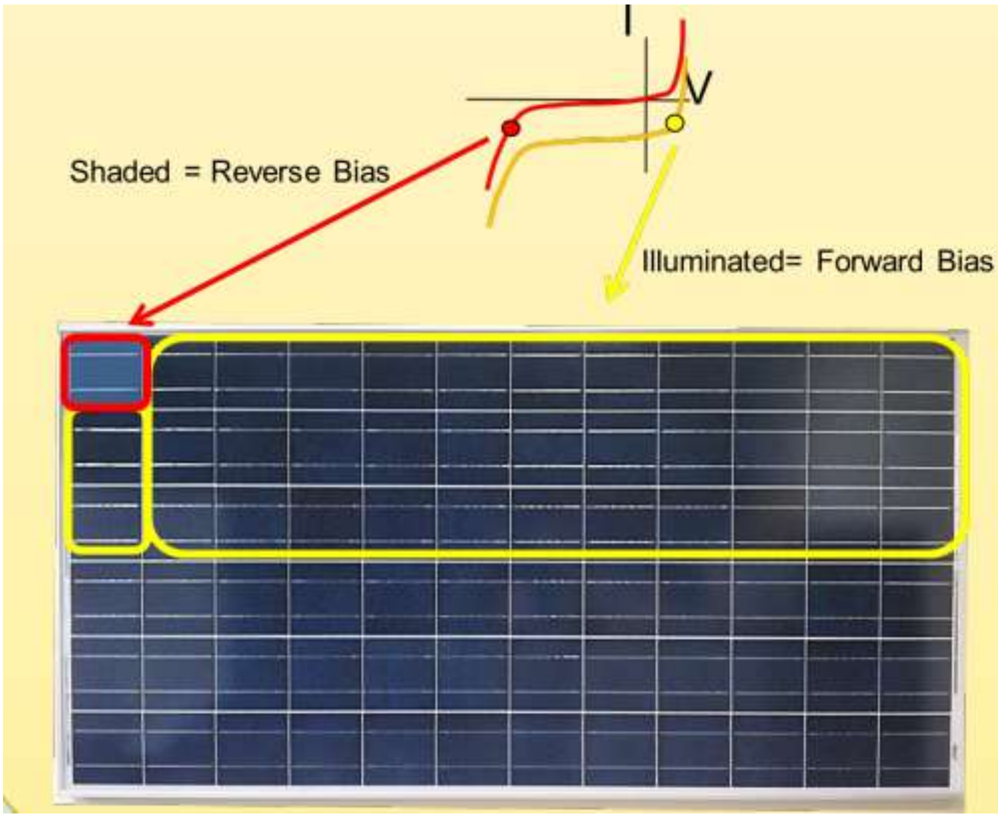

Figure 6: Hotspot

II. Related work

Reference	Year	Proposed work	Technique used/tool used	Outcomes
[7]	2015	Fault analysis related to the Solar PV module	Micro fault Snail fault and hotspot are analysed	The loss of generation of electricity and output are analysed in case of fault analysis
[8]	2010	An automatic supervision has been sued to analyze the fault in PV module.	MATLAB simulink tool has been used to analyse the parameters	The losses named as thermal capture losses and miscellaneous losses have been measured.
[9]	2008	A circuit based PV module has been proposed. 3KW PV module has been	PSIM software has been used	The IV and PV features have been measured at different surface temperature

		used to analyse the correction function		
[10]	2017	T-test and F test are used to recognize the crack on the pv module	Lab VIEW tool has been used to measure the I-V and P-V characteristics.	The technique classified up to 60% of cracks which has a important effect on the entirely power produced by PV modules.
[11]	2017	Grid connected pV array has been used to analyse the fault. Fuzzy logic has been used as a classifier that comprises of two inputs named as PR and VR.	LAB VIEW software has been used to measure the parameters.	The parameters such as VR (Voltage ratio) and PR (Power ratio) have been measured. By using fuzzy logic the fault detection rate has been increased up to 98.8 %.

III. Parameters measured

The parameters that are used to measure the efficiency of the PV cell are defined below:

i. Irradiance

Irradiance is a measure of solar energy and is defined as the speed at which solar energy falls on the ground. The unit of power is Watts (abbreviated W). In the case of solar radiation, we usually measure the power per unit area, so the irradiance is usually expressed in W/m2 - that is, watts/square meter. The irradiance that falls on a surface may change from time to time, which is why it is important to remember that irradiance is an important measure of power - the rate at which energy falls, not the total amount of energy.

ii. Cell to module factor

$$\boldsymbol{CM = \frac{P_{m\times n,module}}{\sum p_{m\times n,cells}}}$$

$Here, Pm \times n$ represents the maximum output power of the two different module and two different cells.

iii. Power losses

It is defined as the ratio of change in power to the total input power. Mathematically it can be represented as

$$Power\ loss(\%) = \frac{\Delta p_{max}}{P_{max}}$$

$Here, P_{max}$ $represents\ the\ maximum\ puwer,$ whereas Δp_{max} represents the change in maximum power point.

IV. Conclusion

In this paper, we are discussing about the fault detection methods used in PV array system depends upon the power losses analysis. A detail description of fault occurs in PV module along with power cells have been measured. The purpose of this paper is to quantify the loss of production and efficiency, and to approximate the level of failure through mathematical modelling if the fault starts to develop. In addition, different standard PV module testing procedures used around the world are discussed in order to accurately detect faults. By understanding the effects of faults, scientists can develop more efficient faulty photovoltaic modules and develop alarm systems in the event of failure-related losses.

References

[1] Acciani, G., Falcone, O., & Vergura, S. (2010). Defects in poly-Silicon and amorphous Silicon solar cells. In *International Conference on Renewable Energy and Power Quality, Spain*.

[2] Kajari-Schröder, S., Kunze, I., Eitner, U., & Köntges, M. (2011, June). Spatial and directional distribution of cracks in silicon PV modules after uniform mechanical loads. In *Photovoltaic Specialists Conference (PVSC), 2011 37th IEEE* (pp. 000833-000837). IEEE.

[3] Dhimish, M., Holmes, V., Dales, M., & Mehrdadi, B. (2017). Effect of micro cracks on photovoltaic output power: case study based on real time long term data measurements. *Micro & Nano Letters*, *12*(10), 803-807.

[4] Mitzi, D. B., Gunawan, O., Todorov, T. K., Wang, K., & Guha, S. (2011). The path towards a high-performance solution-processed kesterite solar cell. *Solar Energy Materials and Solar Cells*, *95*(6), 1421-1436.

[5] Naumann, V., Lausch, D., Hähnel, A., Bauer, J., Breitenstein, O., Graff, A., ... & Hagendorf, C. (2014). Explanation of potential-induced degradation of the shunting type by Na decoration of stacking faults in Si solar cells. *Solar Energy Materials and Solar Cells*, *120*, 383-389.

[6] Rath, J. K. (2003). Low temperature polycrystalline silicon: a review on deposition, physical properties and solar cell applications. *Solar Energy Materials and Solar Cells*, *76*(4), 431-487.

[7] Karim, I. A. (2015, May). Fault analysis and detection techniques of solar cells and PV modules. In *Electrical Engineering and Information Communication Technology (ICEEICT), 2015 International Conference on* (pp. 1-4). IEEE.

[8] Chouder, A., & Silvestre, S. (2010). Automatic supervision and fault detection of PV systems based on power losses analysis. *Energy conversion and Management*, *51*(10), 1929-1937.

[9] Chao, K. H., Ho, S. H., & Wang, M. H. (2008). Modeling and fault diagnosis of a photovoltaic system. *Electric Power Systems Research*, *78*(1), 97-105.

[10] Dhimish, M., Holmes, V., Mehrdadi, B., & Dales, M. (2017). The impact of cracks on photovoltaic power performance. *Journal of Science: Advanced Materials and Devices*, *2*(2), 199-209.

[11] Dhimish, M., Holmes, V., Mehrdadi, B., & Dales, M. (2017). Multi-layer photovoltaic fault detection algorithm. *High Voltage*.