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Analysis of different microcracks shapes and the effect of each shape on performance of PV modules

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Abstract. Photovoltaic solar panels became the world's largest distributed Renewable technology through its easy manufacturing and installation, moreover, the cost of photovoltaic panels falls continuously which provided a safe environment to investors to invest in such systems. The Photovoltaic solar panel made from different layers starting from anti reflected coated glass layer, encapsulation material, solar cells matrix another encapsulant layer and back sheet. This structure does not provide the needed protection to the solar cells encapsulated inside and there will be a possibility of microcracks happen at different stages of the project life cycle starting from the production, transportation, installation, cleaning and operation, and maintenance stage. Through this research, modules from different projects were tested to see the microcracks and their effect. Results show that those cracks can cause a power drop up to 3.21% depending on the type of the module. Furthermore, microcracks are classified as minor and major ones based on their shape, dendritic and vertical shapes are resulted to be the most severe ones.
Keywords. Microcracks, solar energy, power drop.

1. Introduction

The need for analysis of microcracks is important since numerous power plants were already installed and started to show some problems, mostly power drop due to microcracks. Taking into consideration that changing any panel from a project without performing a root cause analysis diagram and finding the effect on the long term is a real loss firstly to the project owner and secondly to the environment which is our top priority. Jordan is the second most attractive environment for renewable energy and energy efficiency investments in the region with only 1.3 millions of tons of Carbon Dioxide per terawatt hours
(MtCO2/TWh) in CO_2 emissions from fuel combustion/electricity output, the country is doing relatively well in the energy sector despite a lack of natural resources additionally 100% of Jordan's total population has access to electricity and access to clean fuels and technology for cooking. The energy market is now poised to become a leading regional example of non-oil dominated energy mix and diversified energy sources [1]. According to the Ministry of Energy and Mineral Resources Report (2018) which referred to (1130 MW) installed capacity constituted 11 percent from total electricity generation capacity in Jordan and this capacity is expected to increase to 2,400 megawatts (MW) by 2021 as highlighted in the 2018 report [2]. If that plan is applied carefully and the expectations are

achieved, then the renewable energy would constitute 20 percent of Jordan’s total electricity generation capacity compared to 1 percent in 2014.
According to the ministry’s report, renewable energy projects that are set for completion in 2021 will have a total capacity of 1,270MW. Photovoltaics (PV) have been adopted as a major renewable energy source globally, for instance, India plans to reach up to 60 GW by 2022 [3]. Furthermore, entering the industry of electric vehicles [4]. The construction of PV systems is capital intensive and systems are expected to perform and generate power for more than 25 years [5]. PV solar modules consist mainly from solar cells and other components encapsulated to each other’s and many types of PV solar cells can be used to assemble PV solar modules, Mono-Crystalline (MONO-SI), Poly or Multi-Crystalline (P-Si), Amorphous Silicon (A-Si), Concentrated PV cell (CVP).
The thickness of solar cells (Poly or Mono) varies from supplier to another and the record lab cell efficiency is 26.7% for mono-crystalline and 22.3% for multi-crystalline silicon wafer-based technology. The highest lab efficiency in thin-film technology is 23.4% for CIGS and 21.0% for CdTe solar cells [6].
Material usage for silicon cells has been reduced significantly during the last 13 years from around 16 g/Wp to about 4 g/Wp due to the increased efficiencies, thinner wafers and wires as well as larger ingots [6]. Discussing the overall PV solar panels structure and after assembling all layers as shown in Figure 1 some types of microcracks may grow according to their shape and location in PV module and this grow might happen due to, transport, improper installation, handling, vibration, excessive load, environmental stresses, improper cleaning and during the operation and maintenance stage. It is important to find the impact of each microcrack shape on the performance of the PV module to optimize the power generation from the PV project and reduce the cost of operation and maintenance thereafter.

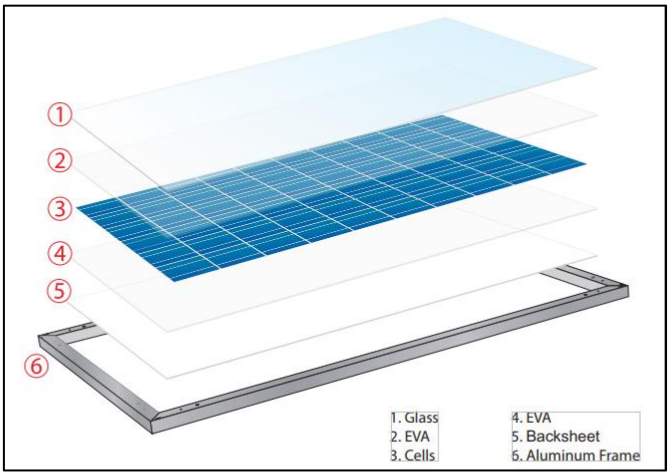


Figure 1. PV solar module structural layers.

The orientation of the microcracks plays an important role in assessing their potential for causing power loss. Microcracks parallel to the cell busbars (vertical) are critical, also dendritic cracks and cracks with multiple orientations. Considering that on average 6% of modules can show cracks after transportation, it is important to assess the type and severity of microcracks before acceptance and installation of modules into a PV system. The shape parameters of the micro-crack pattern are dependent on the EL measurement conditions, the most important of which are the bias current and camera exposure level [7]. Cracks or micro-cracks played a key role in explaining this mechanism, they prevented the moisture from evaporating out of the module, and narrow cracks/ micro-cracks are sturdier than soldered cut lines in preventing moisture getting out [8]. It also explains why there were no snail trails at the edges of cells; they may appear if the humidity is high enough inside EVA and Ag grid lines [8]. This Study will focus on certain types of microcracks which are vertical, horizontal, dendritic, and others such as (PID dark cells on edges, dark cells, and Impact µCracks).

2. Testing and data analyzing

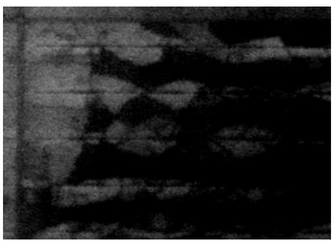
In this work, an analysis of microcracks was performed to find the effect of each microcrack shape on the performance of the PV module. The affected modules disassembled from the project site and returned to the workshop to measure the EL image and analyze the microcrack then I -V curve measured by flasher machine to find the drop in power performance. The EL tester used is equipped with NIR Nikon Camera with HD lens and total resolution ≥16.2 Megapixel and image pixel 405 μm /pixel with testing Cycle of 30 s/Module and this machine is suitable for both monocrystalline silicon and polycrystalline silicon module.

The test procedure was done by loading the module into a loading conveyor then positioned in a way that the camera detects all cells while the EL detector receives the upstream application signal. If the EL detector, probes contact electrodes automatically then the test is done. After testing done the module ejected to offloading conveyor and the images saved to be analyzed. While the Sun Simulator machine was used to test the power and electrical specification, the machine is equipped with Endeas software a class AAA complied with IEC60904-09 concerning spectrum, irradiance non-uniformity, and short-term instability (STI). The Xenon technology spectrum is continuous from 300 nm up to 1,200 nm.

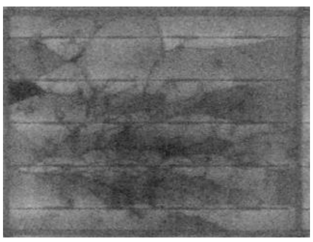
The measurements were done following IEC 61215-2 [9], where module shall be loaded into Sun simulator (flasher) class AAA and a PV reference device by IEC60904-2 shall be used as a reference module of the same size with the same cell technology to match spectral responsivity. Then the Current-voltage characteristics of the sample/module determined following IEC60904 -1 at a specific set of irradiance and temperature conditions.

3. Data Analysis

The manufacturing processes might affect the cells and cause different types of microcracks. The most effective shape is dendritic when the cell comes darker in color, it also noticed that the more dendritic darks cells the more power drop recorded. The key role for power drop is having dark areas in the microcrack itself which makes that area non-active and in dendritic shape, the microcracks spread along with the cells and cut more than one bus bar. In this study, the microcracks during the manufacturing process are neglected and the concentration will be on them after installation. Different projects were analyzed in different locations to find the effect of microcracks and summed up like Figure 2. It was noticed significant power drop in the first module due to having many types of microcracks at the same time besides having dark cells which reduced the power significantly as the cells connected in series in the PV module. Whereas the second module showed significant power drop as well due to having many types of microcracks at the same time and on top of that it had dark areas in two cells. The LID effect for Mono-Crystalline Modules is up to 3 % which is doubled the poly-Crystalline modules. EL images and flasher results of a total of 44 crystalline silicon modules in different locations were taken during the 2019 study. The images and electrical data refer to solar panels not yet installed, others installed in Dabouq, ALQastal, Cairo, AlMafraq, Ein ELBasha, and one transported from China to Amman.



1. Dendritic with dark areas Disconnection for current (Major).



2. Dendritic with no dark area but still (Major) cut all busbars.

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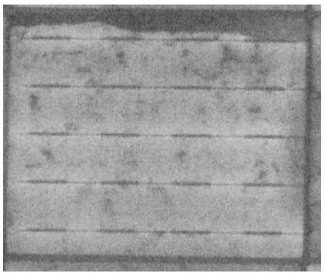
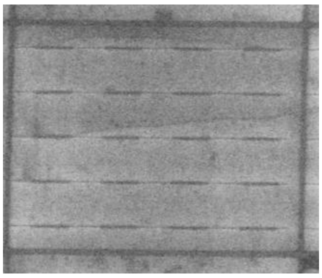
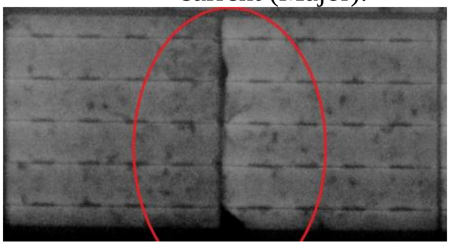


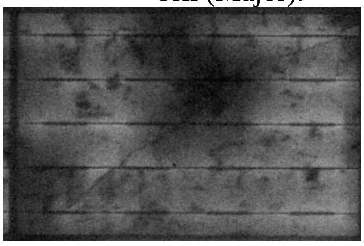
3. Vertical with dark area, disconnection of current (Major).



4. Vertical on busbar, per number per each cell (Major).

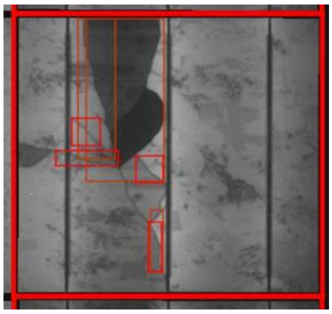


5. V shape on one busbar out of five busbars, cause degradation on long run (Minor).

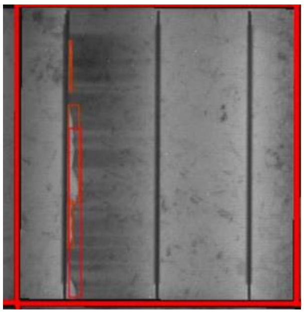


6. Vertical cutting all busbars (Major).

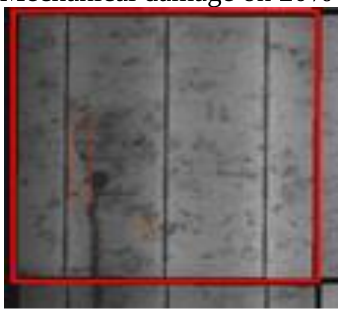
7. PID effect on 90% of the cell (Major)



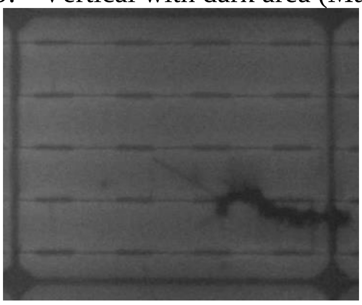
8. Mechanical damage on 20% (Major).



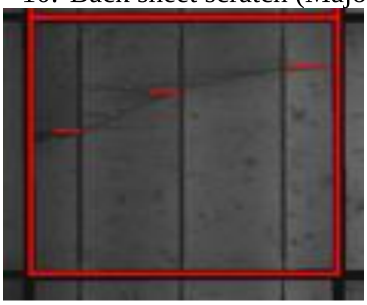
9. Vertical with dark area (Major).



10. Back sheet scratch (Major).



11. Impact and it can be expanded (Major).



12. Horizontal crack (not critical) (Major).

Figure 2. Micro cracks classifications from several projects

Microcracks testing was performed on projects installed in 2016 and 2019, also for poly and monocrystalline cells. Generally, microcracks affect the power generated with an average drop of 1.49% in poly-crystalline modules and 0.55% in mono-crystalline ones. It is noticed that older projects cracks effects are higher than new ones, this is expected because old projects are more vulnerable to weather conditions and other stresses.

4. Conclusion

The quality of PV power plants and projects is very critical to generate the needed power production, long life of the project and the return of investment which investors look for, therefore analyzing the micro cracks is needful to get the optimum benefit. During the installation, operation, and maintenance of the power plant, some kind of defects might happen and in this case, each type of defect must be defined to find the seriousness on the power plant as some of them might cause a significant drop on power and create safety issues afterward. There are many ways of developing microcracks in PV modules starting from the manufacturing process, transportation, improper installation, and improper cleaning.
It is also important to point out that the snail trail appeared visually in some samples mentioned in this study grown in the path of microcracks where every microcrack shown in such samples had snail trail but not grown nor increased by time as long as the source of microcracks eliminated.
Therefore snail trail is visual appearance correlated to microcracks but it will not appear if there is no source of micro cracks and there were many research and development done on this matter to overcome this problem and hide the snail trail but still the microcracks have existed as there are many reasons of developing them. Microcracks effect can be classified as a major one on the module if it is for example in vertical shape, power reduction can increase significantly. Therefore, this study aims to classify the micro cracks to know whether there is a need to change the modules or not. Power reduction is expected accordingly where values vary 0.84% to 3.21% power drop in poly-crystalline modules, and 0.22% to 0.89% in mono-crystalline ones.

5. References

[1] PI Berlin 2019 *Industry Trends in PV Module Quality from over 250 Factory Audits*
[2] Anon 2018 *Annual report, Ministry of energy and mineral resources-Jordan*
[3] Department of Electrical Engineering, National Institute of Technology Rourkela, Dist. Sundargarh, Odisha-769008, India, Tarai R K and Kale P 2016 Validation of predictive models to estimate annual PV production: A case study of odisha *ijsgce*
[4] Department of Electrical and Electronic Engineering, Kyushu Institute of Technology, Kitakyushu 804-8550, Japan, Kawagoe T, Fuji K, Shiota A, Mitani Y and Qudaih Y S 2014 Construction of power supply system using electric vehicle for stable power delivery from PV generation *ijsgce*
[5] Anon 2019 *An Effective Method On Evaluating Photovoltaic Module Snail Trail* (in SNEC, China)
[6] Dubey R, Vasi J, Chattopadhyay S, Zachariah S, Rambabu S, Singh H K, Kottantharayil A, Arora B M, Narasimhan K L and Shiradkar N 2018 On-Site Electroluminescence Study of Field-Aged PV Modules *2018 IEEE 7th World Conference on Photovoltaic Energy Conversion (WCPEC)* 2018 IEEE 7th World Conference on Photovoltaic Energy Conversion (WCPEC) (Waikoloa Village, HI: IEEE) pp 0098–102
[7] Dhoke A, Sharma R and Saha T K 2018 PV module degradation analysis and impact on settings of overcurrent protection devices *Solar Energy* **160** 360–7
[8] Commission J I 2018 *Energy sector profile*
[9] F. ISE 2019 *Photovoltaics Report* (Fraunhofer ISE, Frieburg)

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