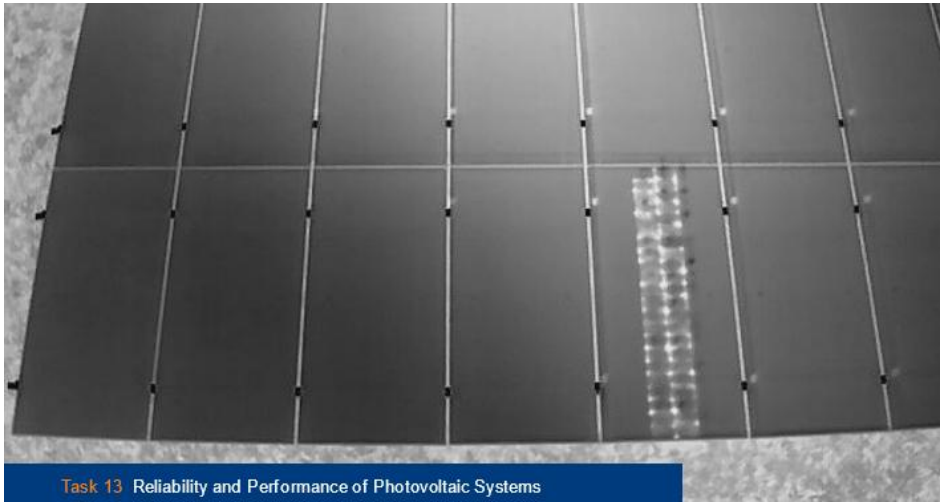

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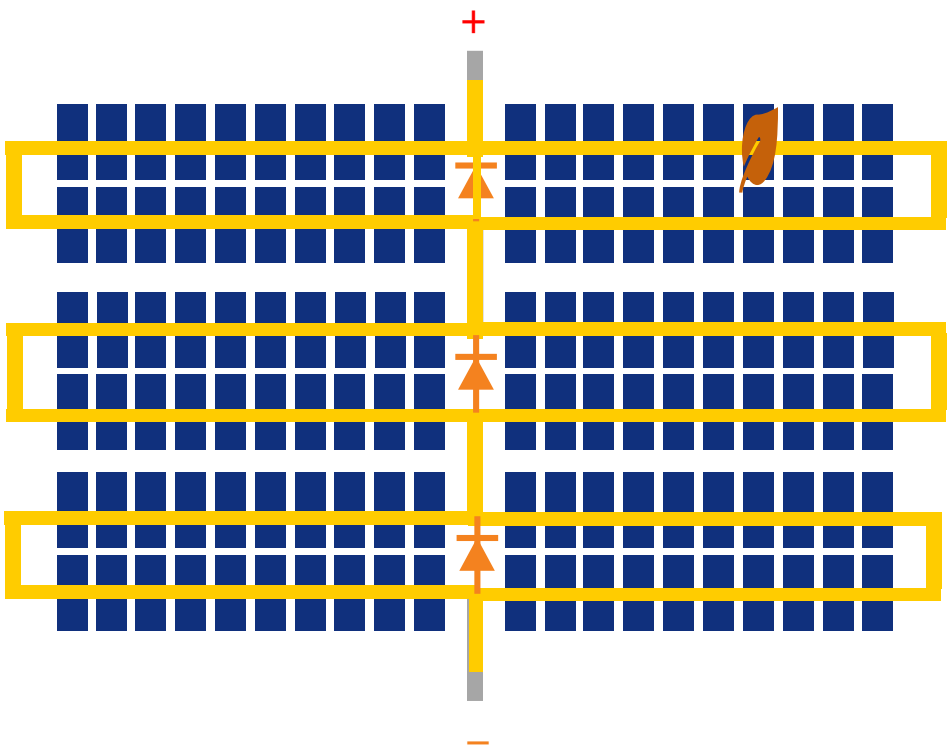
How to deal with cold solder joints in JB of current module designs

Marc Köntges ISFH, Jay Lin PV Guider

DTU, Roskilde, DK, 29th – 30th April 25

Function of Bypass diode



- Bypassdiodes avoid local high breakthrough currents of solar cells in the case of shading
- Voltage at a shaded cell is below voltage of a substring
- Electric currents of cell strings and bypass diode add up to I_{mpp} of the inverter
- ➔ The bypass diode limits the dissipating power to the maximum power of one module substring

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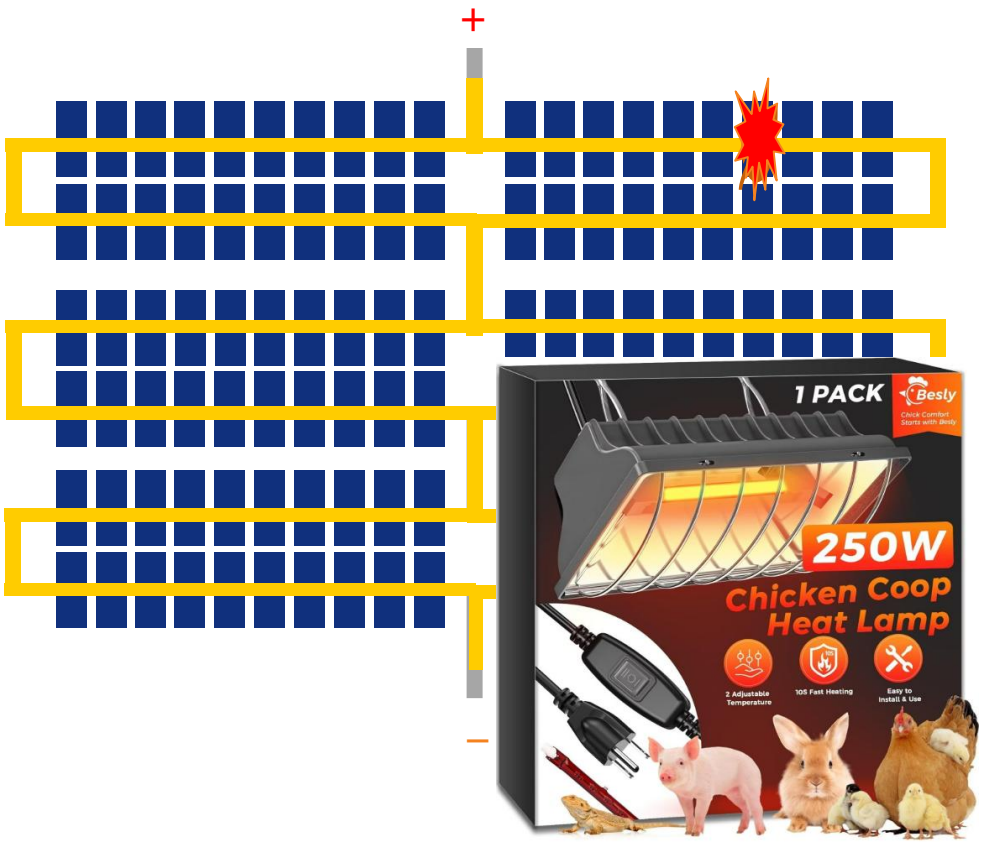
What if there is no bypass diode?



- Shaded cell voltage gets negative: typically between -15 V...-25 V
- The maximum dissipating power can now be powered by the voltage of the full module string
- As we have -15 V… -25 V per cell we have at I_{mpp} ~10 A a power dissipation of 150-250 W per cell.
- ➔ Cell temperature can rise above 150°C
- ➔ Up to 600 V between cells in one substring

What is the origin?

Manufacturer faults

- Cold solder- unstable equipment temperature → Poor internal QA
- Rebounded ribbon- insufficient press during soldering
- Ribbon cut too short- human (or equipment) error
- EVA residual- short ribbon with too much EVA
- Layup dislocation- ribbon is too short to be well soldered

Inherent risks of butterfly module

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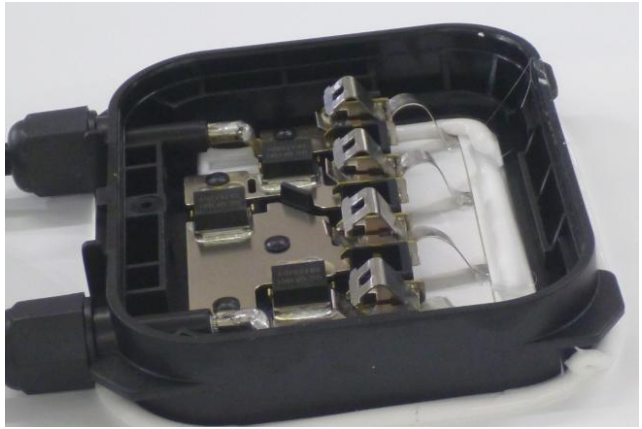
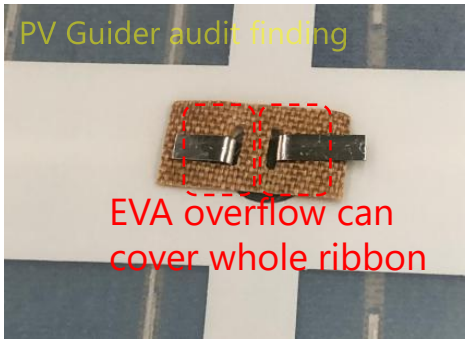
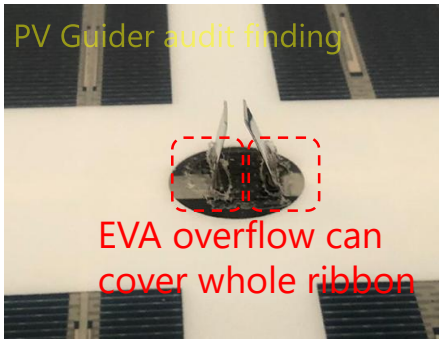
Ribbon length makes the difference

Conventional junction box



Junction box for butterfly module





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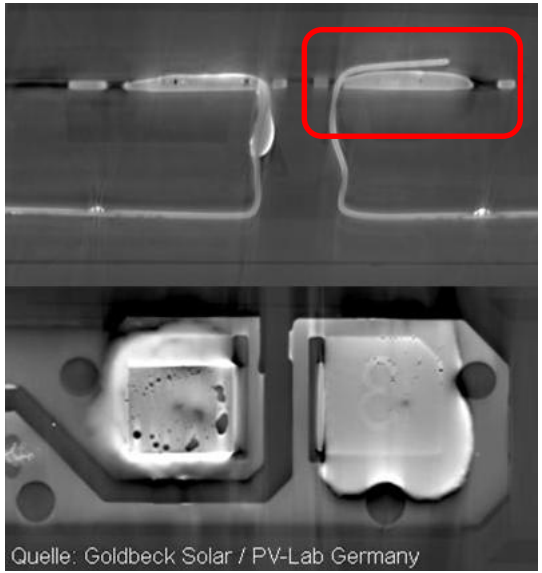
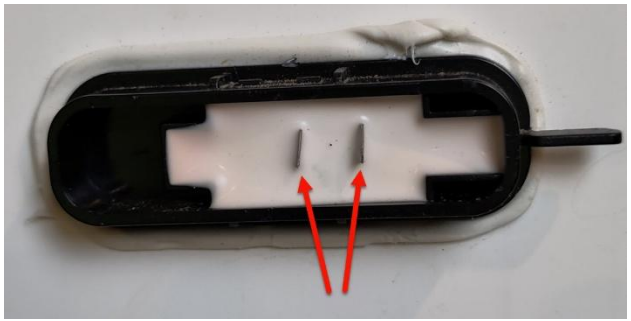
Rebounded ribbon

Short ribbon is stiffer
and easy to rebound



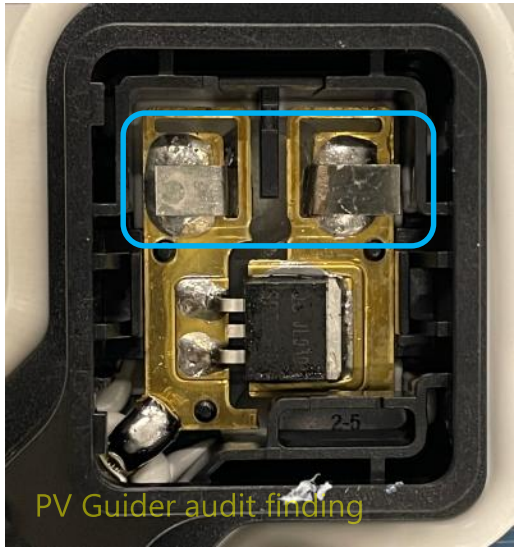


https://photovoltaikbuero.de/pv-know-how-blog/
fehlerhafte-loetkontakte-an-fabrikneuen-photovoltaikmodulen/

- Press time for soldering must be adjusted properly
- Inspection of solder joint required

Ribbon cut too short

Normal length



Ribbons too short

- High precission required for ribbon length and positioning

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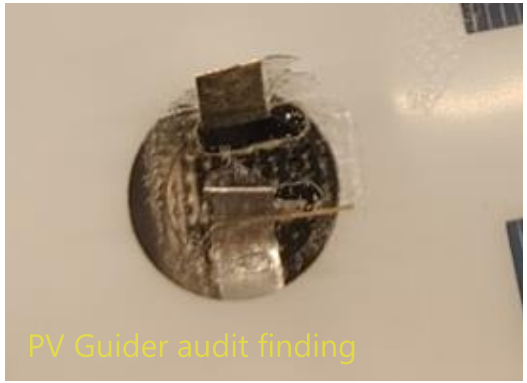
EVA Residual

Short ribbon is easy to be covered by overflowed EVA

It’s very difficult to remove the EVA.

And no one do it in the production !



- Require stable proces without lamination material on ribbon

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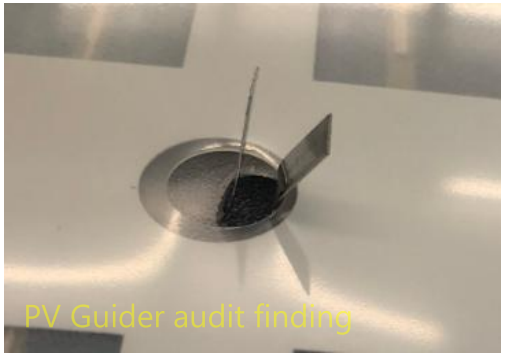
Layup Dislocation

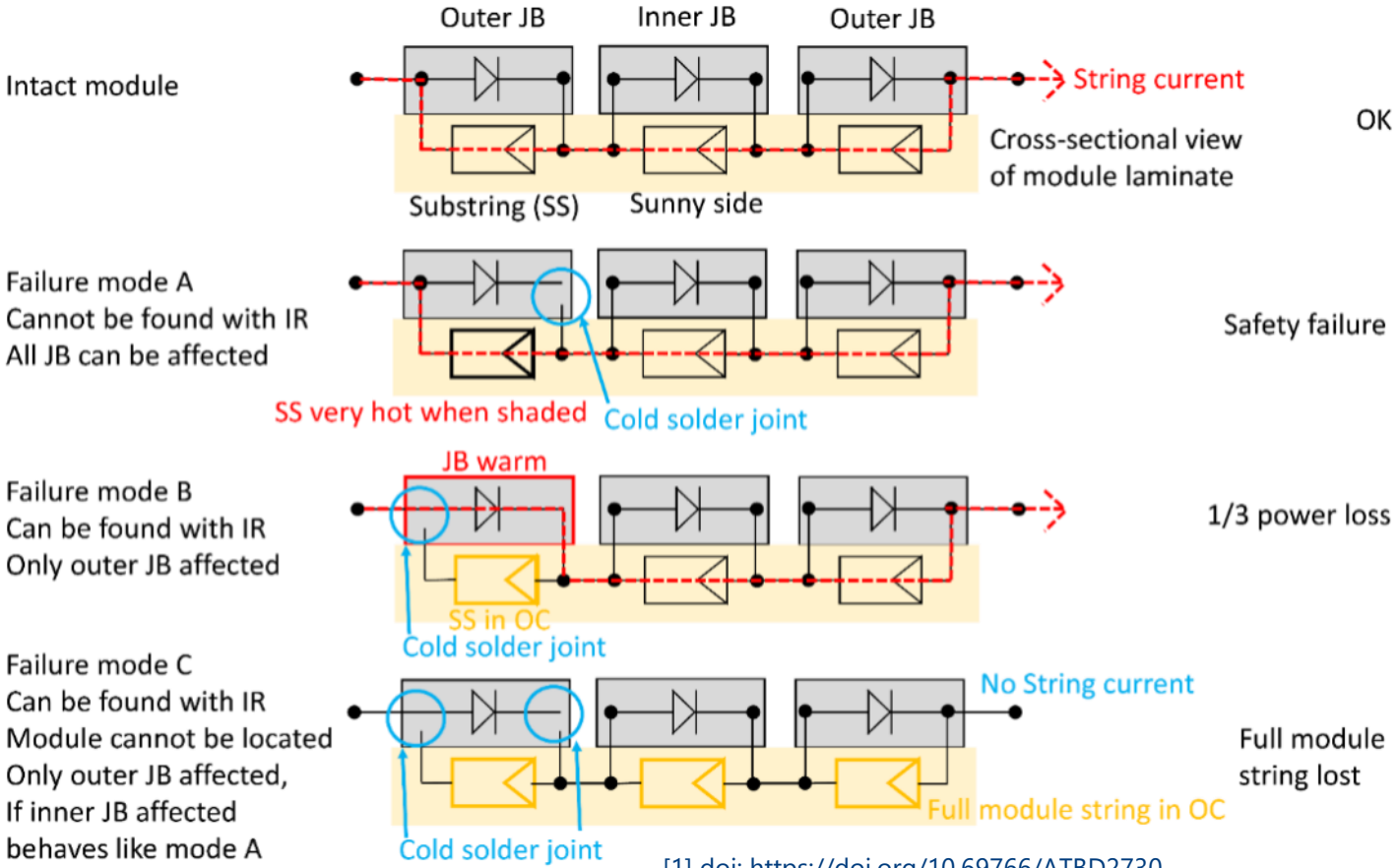
Layup dislocation makes one ribbon too short



One ribbon is too short

- High precission required for layup positioning

What combination of failure may happen



[1] doi: https://doi.org/10.69766/ATBD2730

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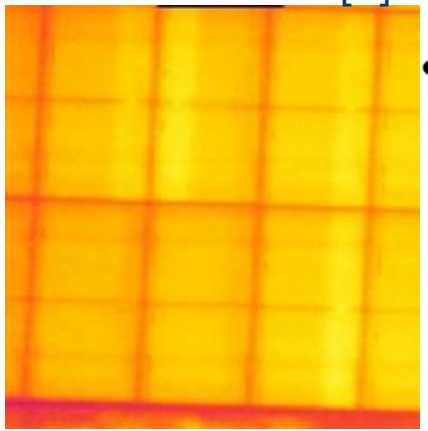
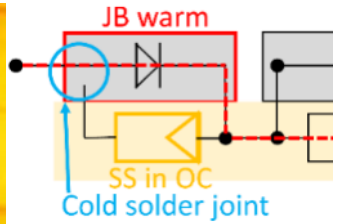
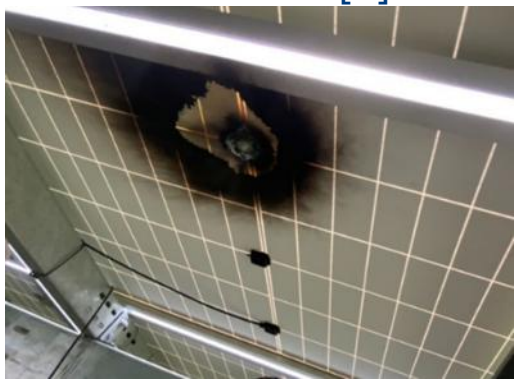
Which detection methods exist?

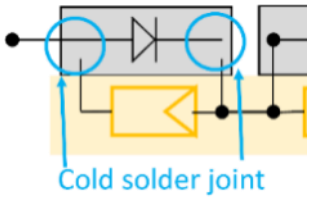
Failure mode B [1]





Failure mode C [1]





Failure mode B and C

- Use standard TG inspection
- Homogenious silightly hotter substrings together with hot junction box ➔ failure mode B
- Full string is not active in TG inspection ➔ failure mode C
  Visula inspection needed

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[1] doi: https://doi.org/10.69766/ATBD2730

Which detection methods exist?

Failure mode A [1]

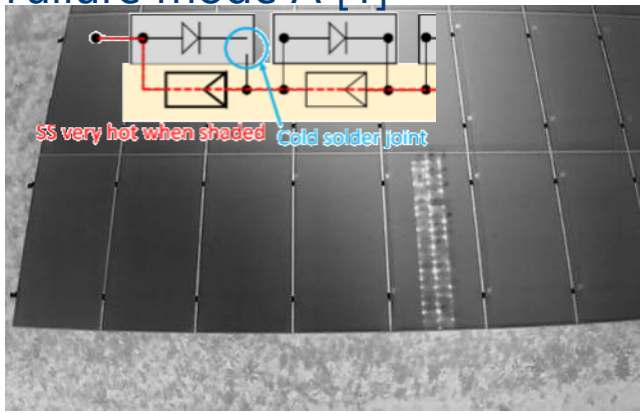
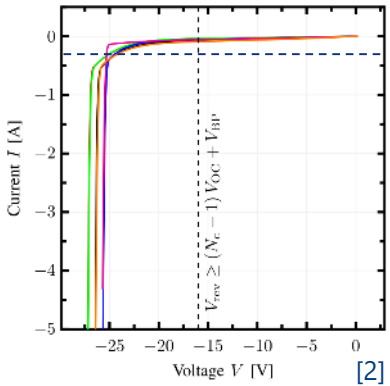


Image: photovoltaikbuero Ternus & Diehl GbR



~3% Isc

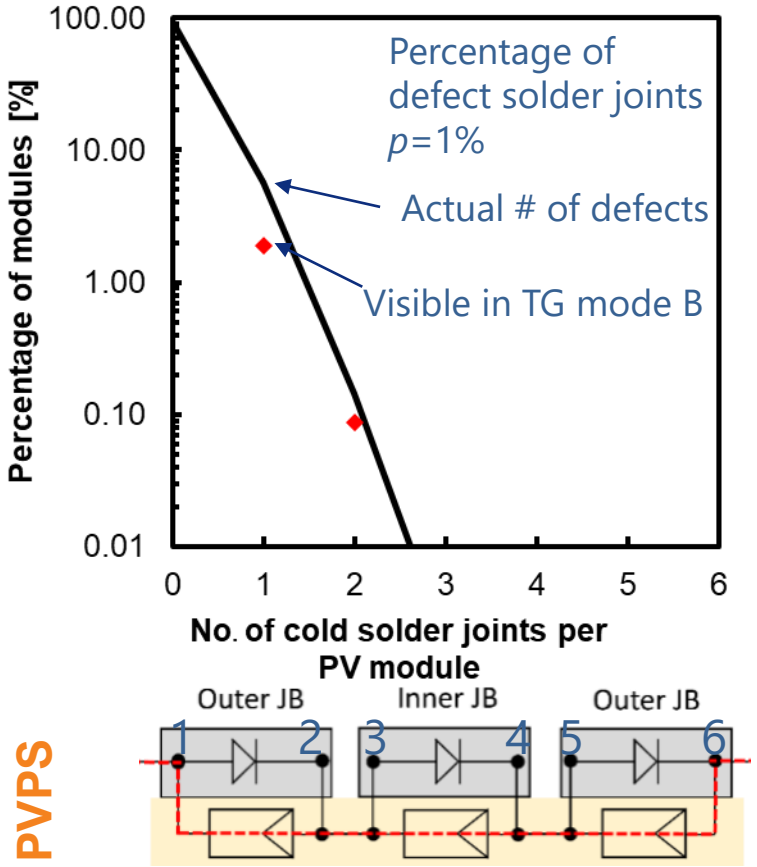
Reverse IV curve of various PERC cells

[2]

- Failure mode A
- Reverse current of 3-5% of Isc in the night applied to module strings, you should get << 50 V
- Across a cell string without BYD a voltage of 15…25 V x 20…24 (cells) = 300…600 V drops
- Search for heated strings with thermographic camera in the night
- Up to two open circuit bypass diodes per string are detectable with a 1000 V power source

[1] doi: https://doi.org/10.69766/ATBD2730
[2] R. Witteck, M. Siebert, S. Blankemeyer, H. Schulte-Huxel, and M. Köntges, "Three Bypass Diodes Architecture at the Limit," IEEE J. Photovoltaics, vol. 10, no. 6, pp. 1828–1838, Nov. 2020, doi: 10.1109/JPHOTOV.2020.3021348.

How many failure are probably in the system?



- Failure mode B is recognized in TG inspection
- Assuming there is a constant propabilty *p* for cold solder joints
- The distribution of the cold solder joints over the 6 contacts will be a binominal distribution
- Counting all visible mode B defects in TG can be translated to number of all actual defect modules

Defect solder joints p [%]	Defect modules in TG [%] mode B	Actual defect modules [%]
0.1	0.2	0.6
0.2	0.4	1.2
0.5	1.0	3.0
1	2.0	5.9
2	4.0	11.4

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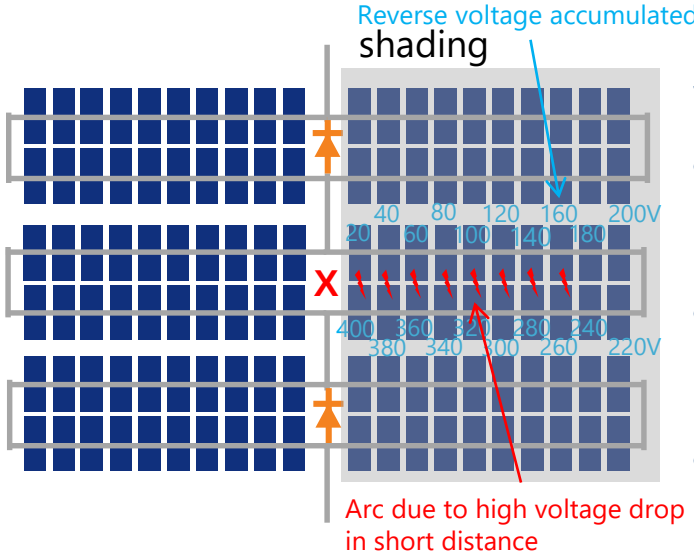
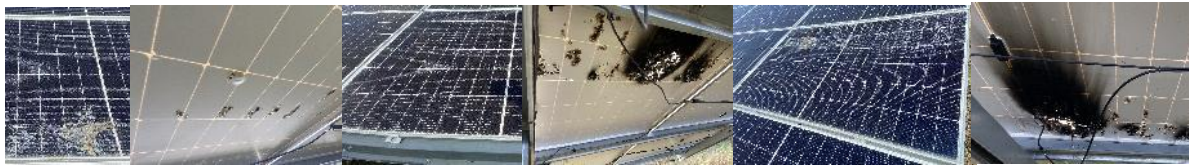
What happens if a BPD is not connected properly?



Shading of the module may cause:

- High reverse voltage across cells -15 V … -25 V without bypass diode
- High reverse voltage may cause hot cells and local breakthrough of cells, often at the cell corners
- High voltage difference between cells of one substring 300…600 V
- High temperatur + high voltage may cause arcing between cells of one substring



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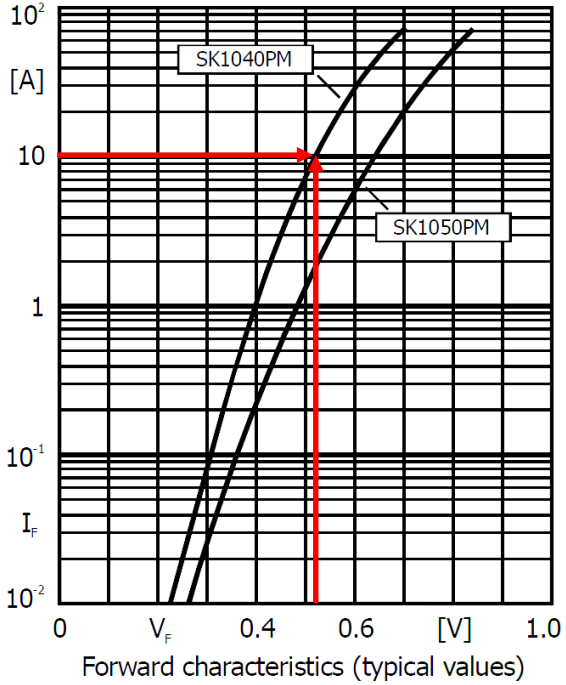
What should we do to avoid the failure?



For 3 bypass diodes V_F x 3

- 1. In the factury the solder joint between cross connect ribbon and solderpad in the JB must be checked visual for „cold solder joints“
- 2. And during flash/EL testing apply a reveres voltage and the current through the bypass diodes should be in a certain current range (according to data sheet of the bypass diodes)
- This enables to identify high resistive contacts
- Alternative to 2. use method defined in IEC 61730-2:2023 Annex A5 a) or b) but not c)

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What should we do if the failure is in my system?

- The failure mode B+C will be recognized in standard IR inspection
- If there is one mode B+C case one must check the whole system for failure mode A+B+C by the suggested methods or alternatives
- We expect ~3 times more defect moduls than # of mode B cases in IR inspection
- Cold solder joints get worse with time. Each year IR inspection should be done.
- Start with shaded system parts
- The inspection rate could be set to normal if no additional failure mode B or C is found any more

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Conclusion

- If failure mode B and C is detected in your system do a 100% search for mode A
- Failure mode B result in at least 1/3 power loss and C in full lost string
- Actual defect modules are typically 3 times the failure mode B rate (for $p \leq 1\%$)
- Failure mode A is costly to find
- All failure mode may result in a fire
- 100% inspection in the production is mandatory
- However, stock items still may have this failure

New TASK13 phase starts in 2026.
Contact me if you want to be part of it!

Thank you for your attention

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