



SOLAR CAR CONFERENCE 2023



Maximum Power Point Tracking of Solar Array

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Elmar

first solar car race: World solar challenge 2013, Solar Team Twente

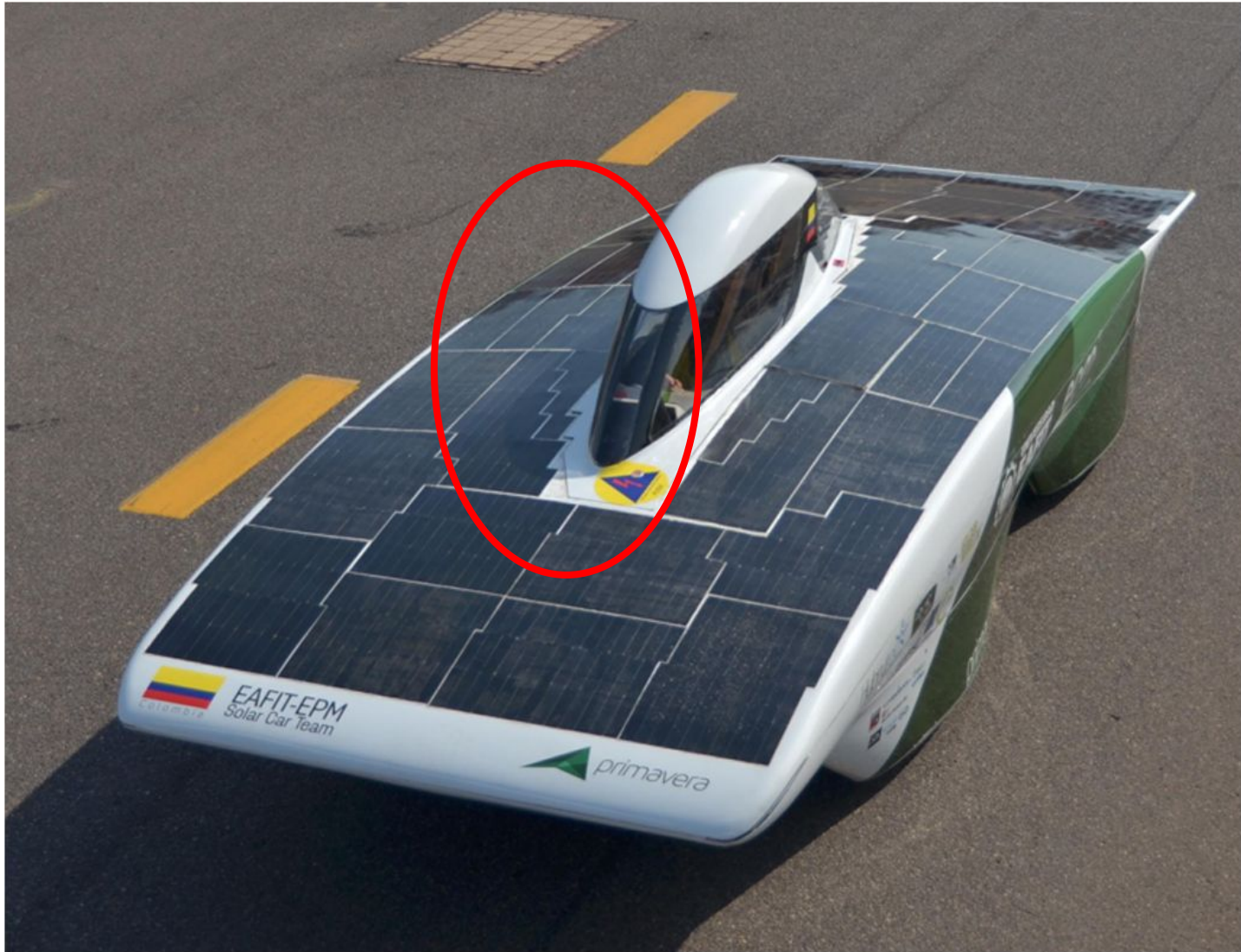
now founder of Elmar Solar (sold MPPT's to WSC winner in 2019)



Outline

- Solar car examples
- Solar cell modeling / local maxima
- Diodes
- MPPT efficiency
- Series MPPT's
- DMPPT's

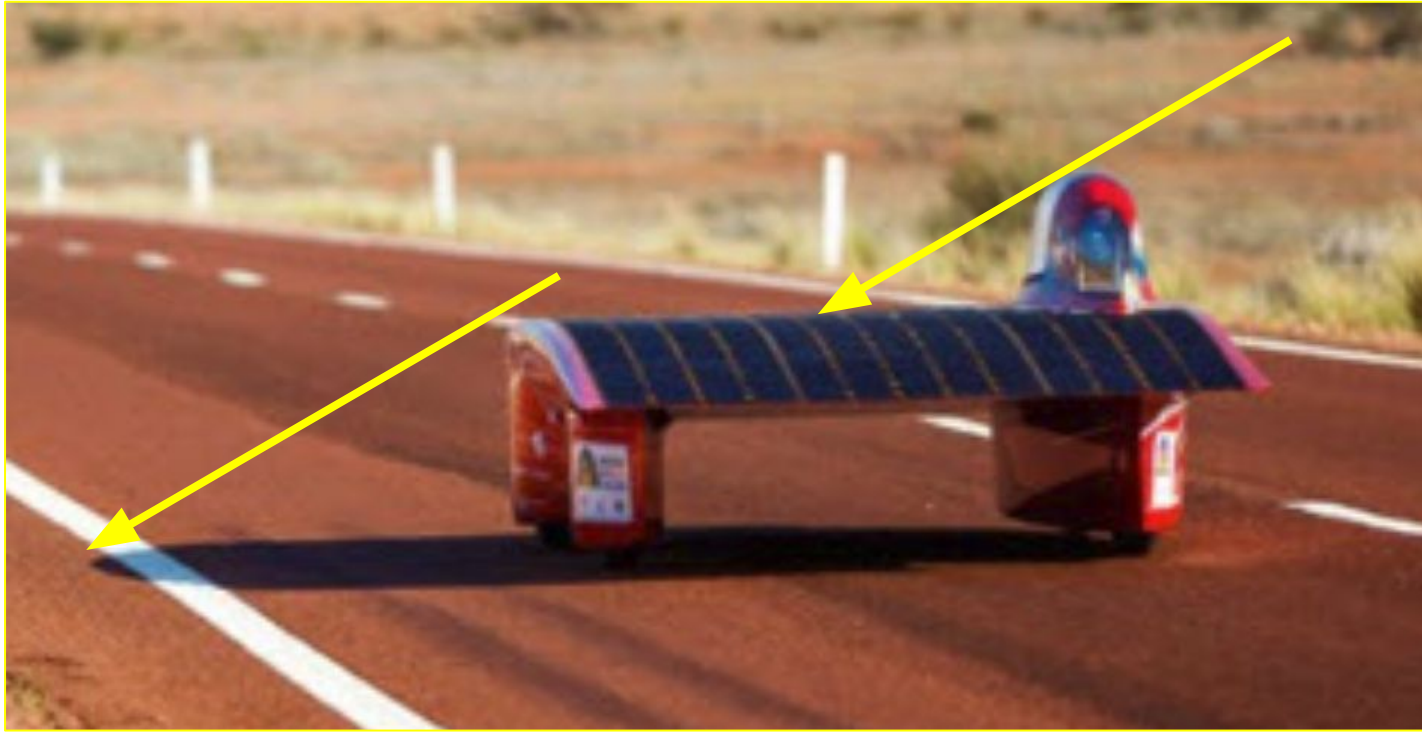
Examples



Canopy shade !!!



Canopy shade !!!



Different angle = different irradiation



Simple solutions

No curve and no shade → No problem!



No solar cells near the canopy = no shaded cells

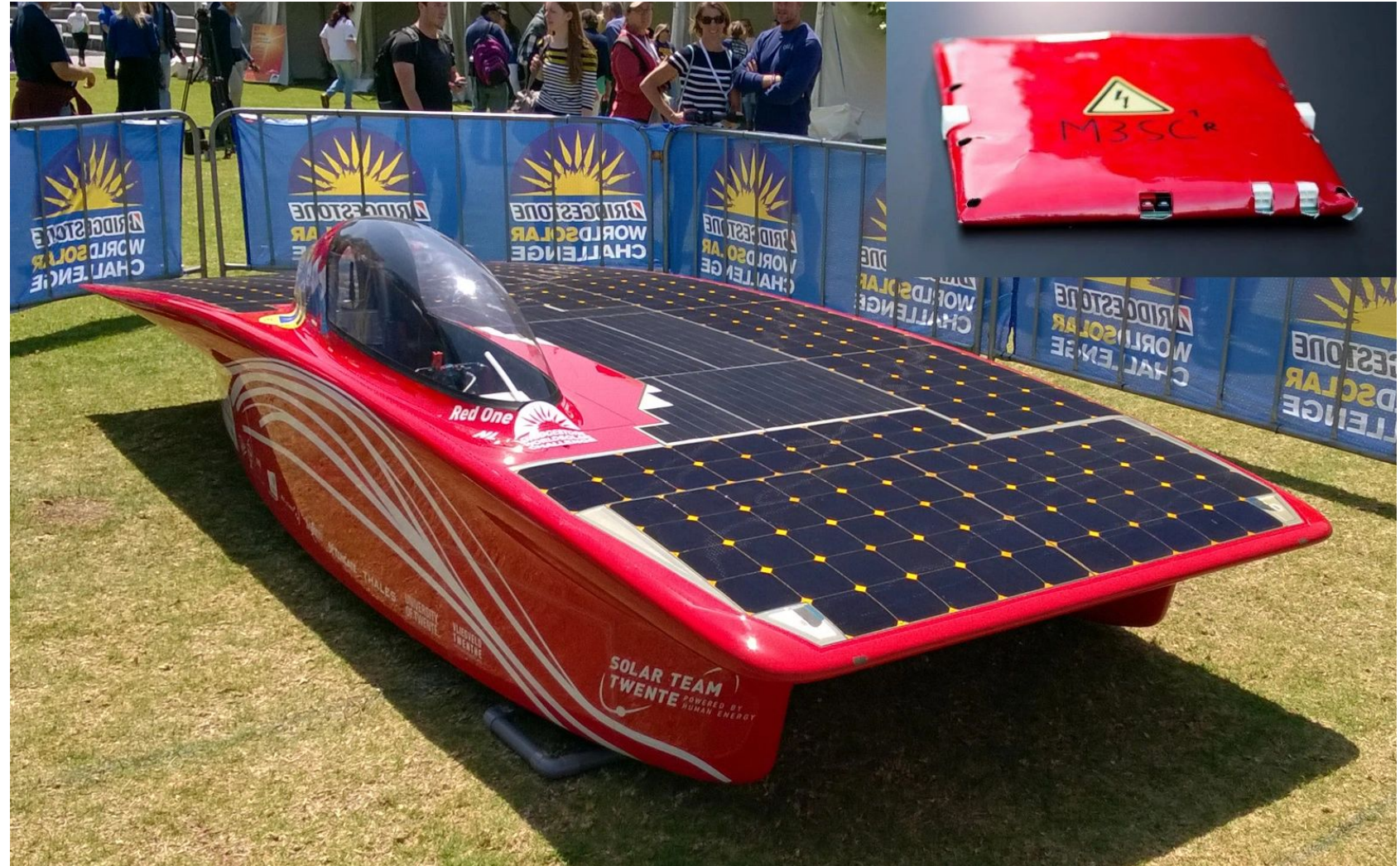


Smaller cells = smaller groups



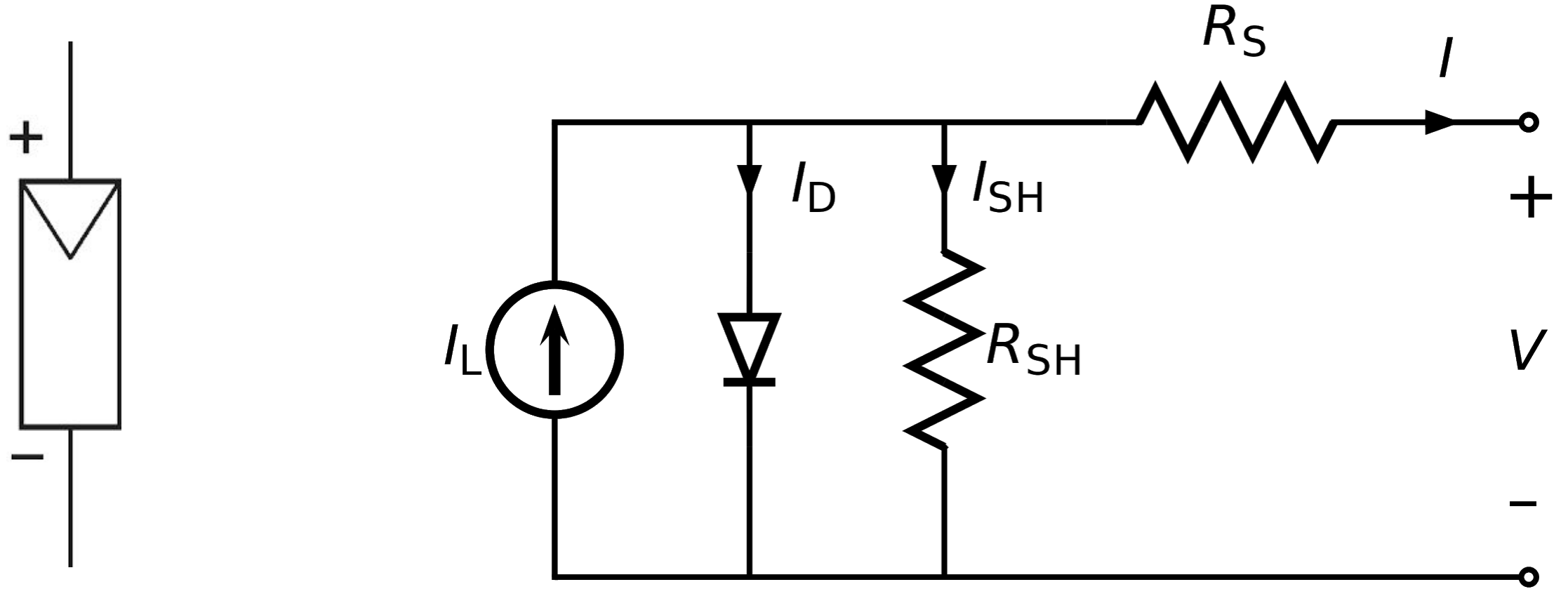
smaller cells in shaded areas

is a good idea!

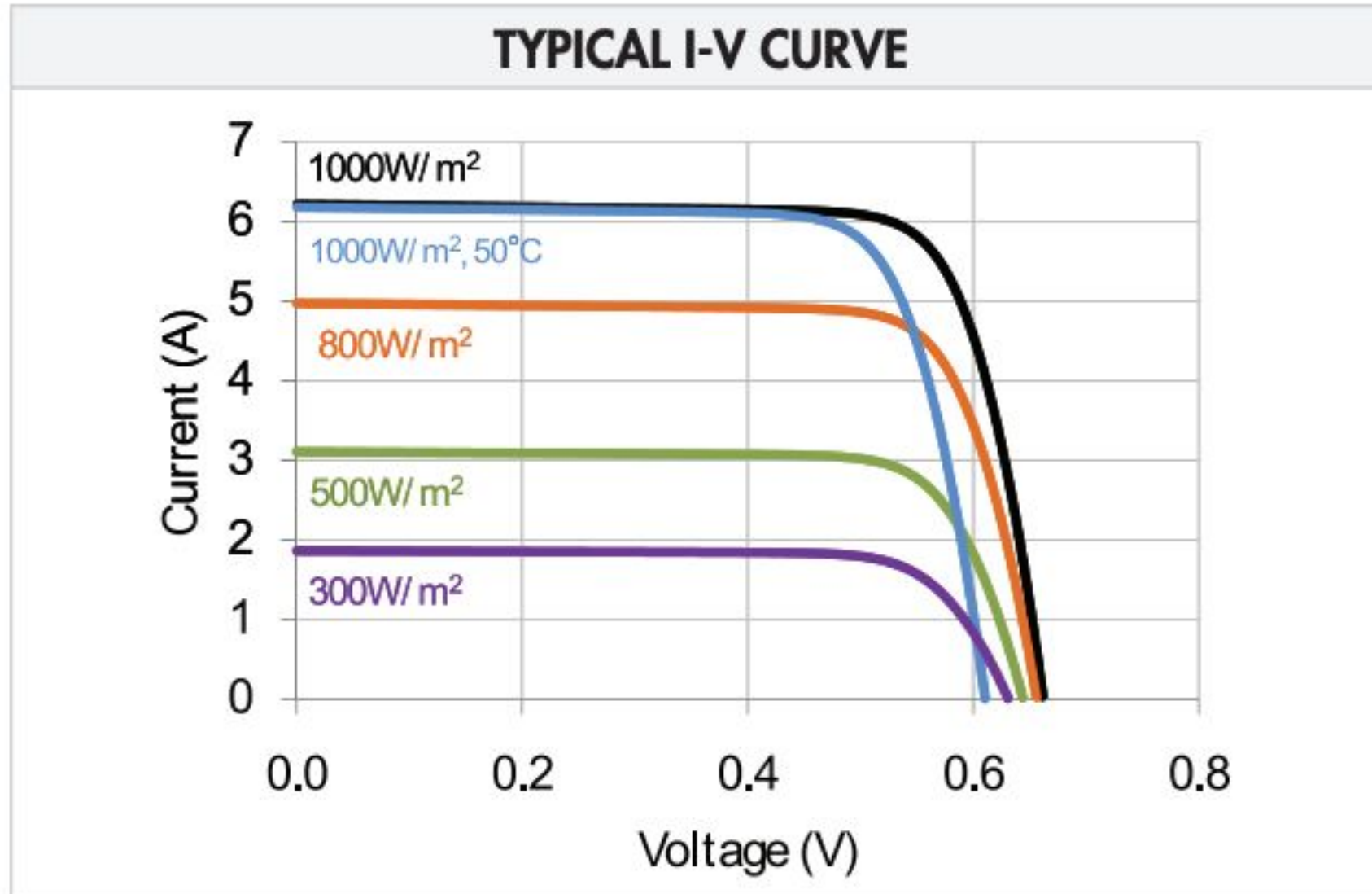
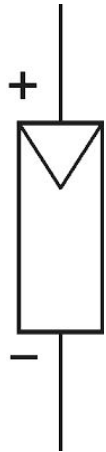


Solar cell modeling

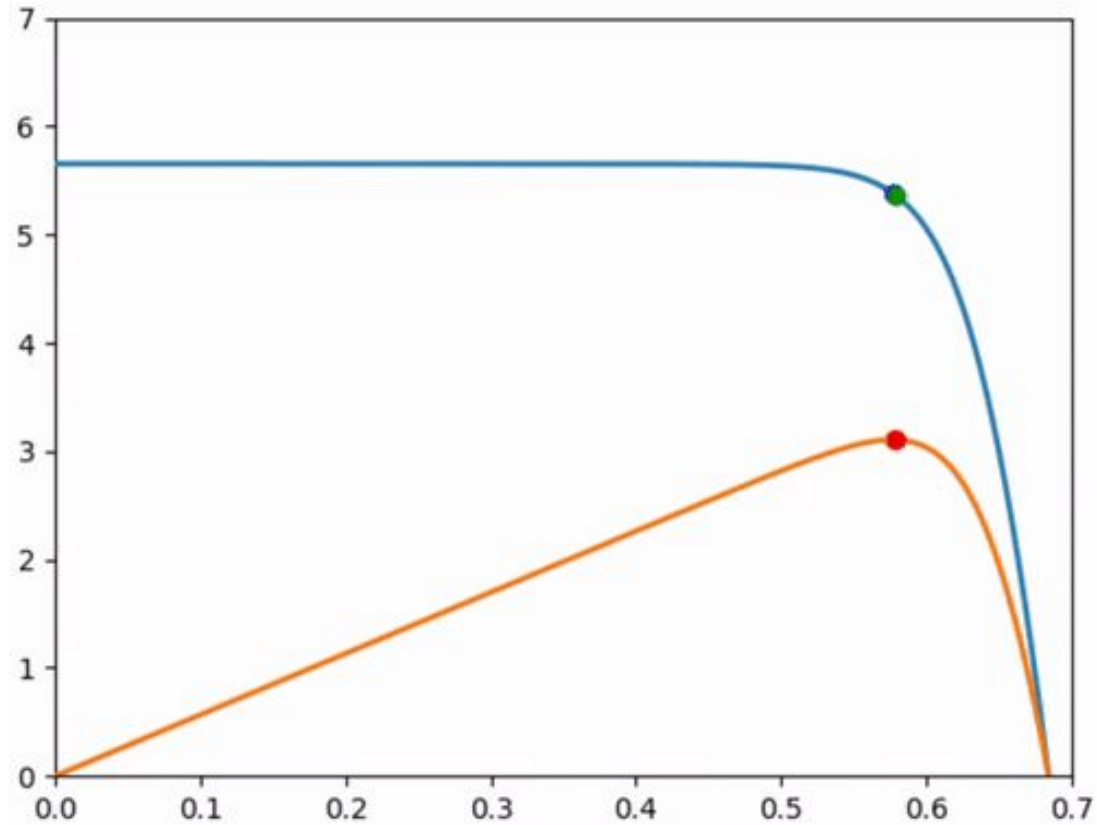
Solar cell model



IV curve for different irradianations



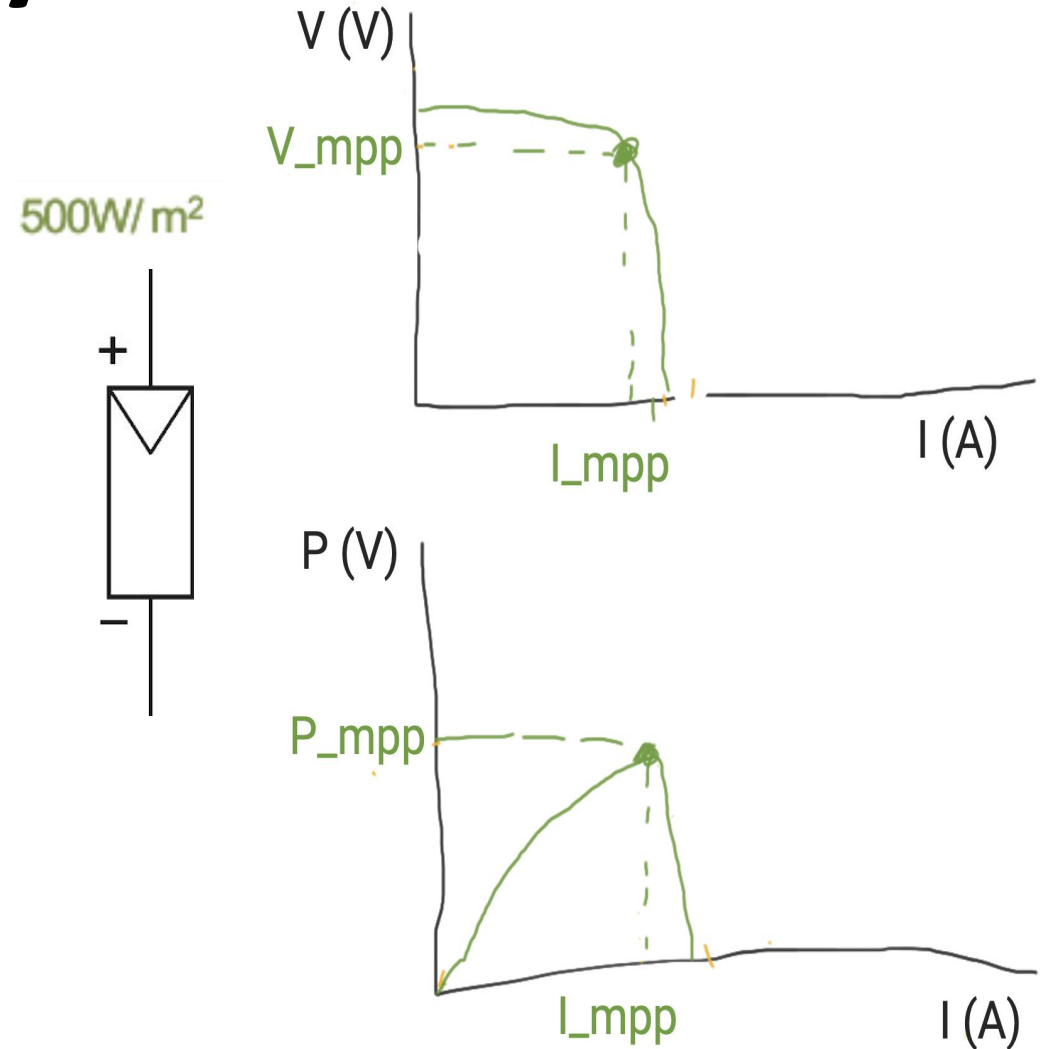
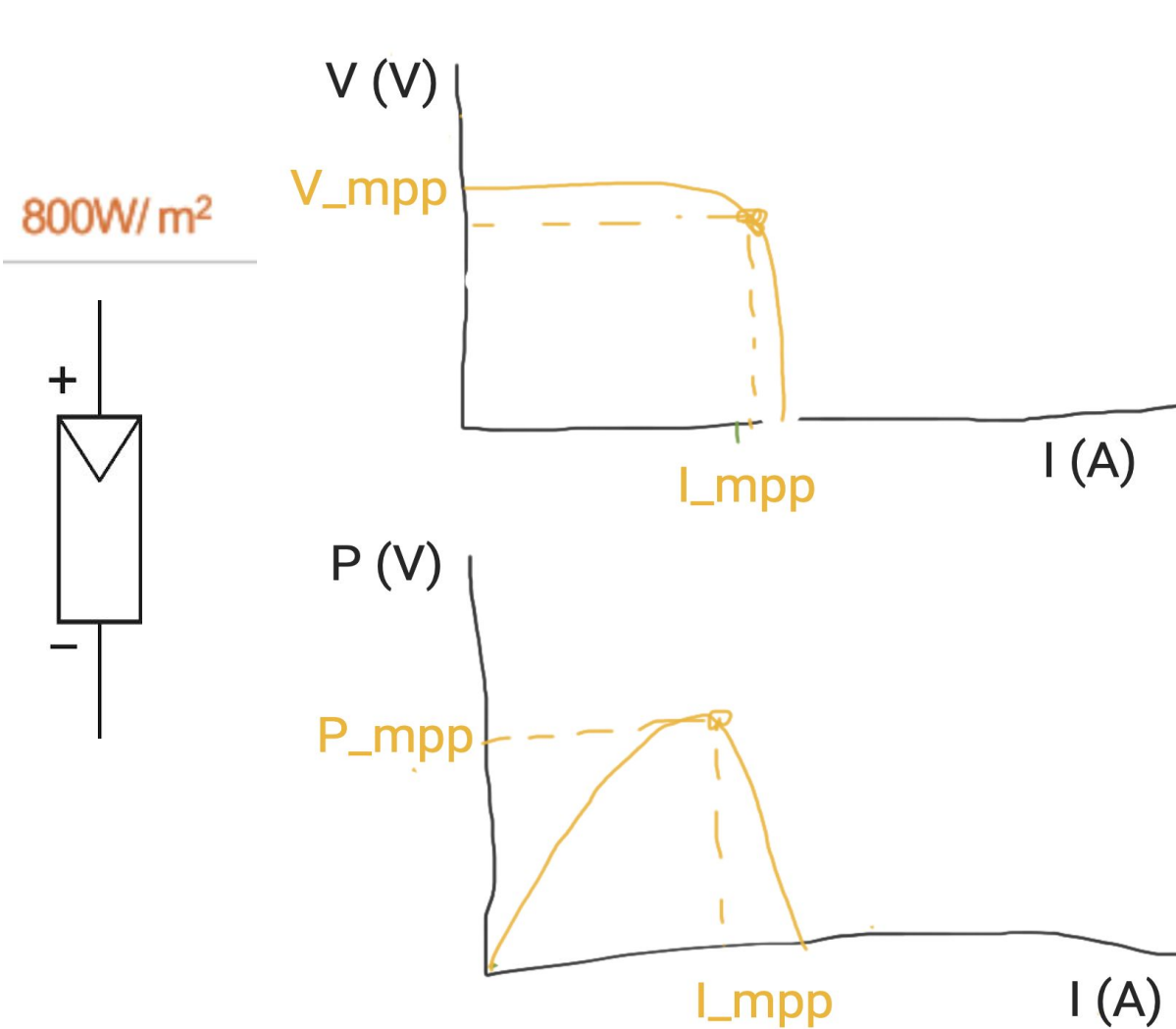
Example of dynamic MPPT tracking



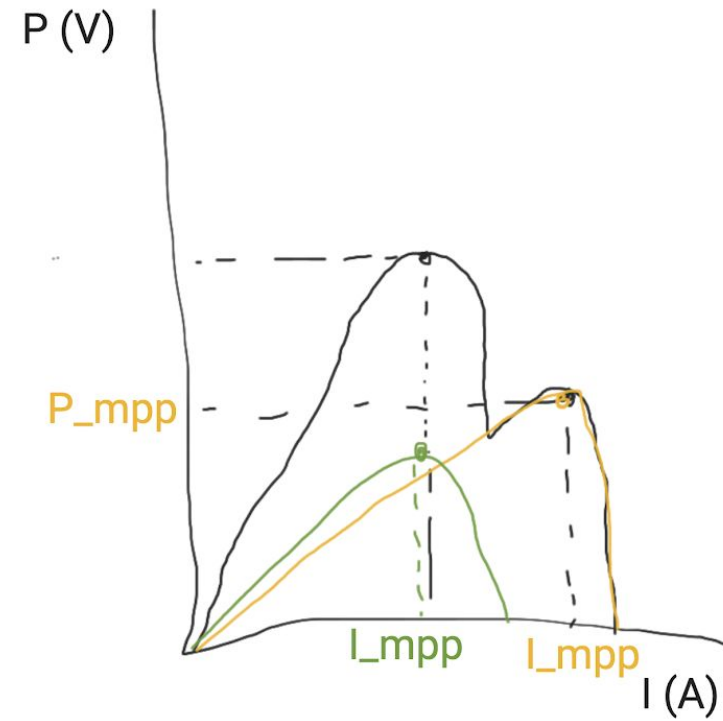
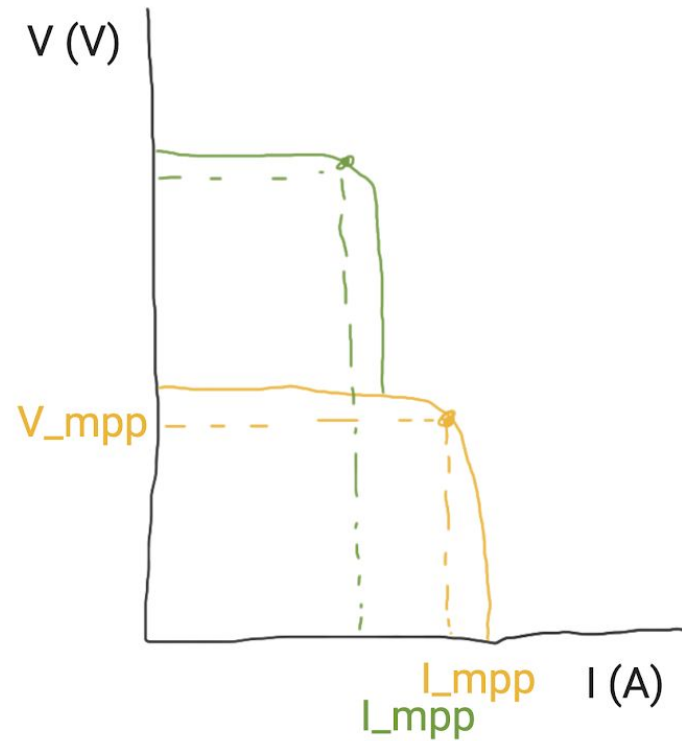
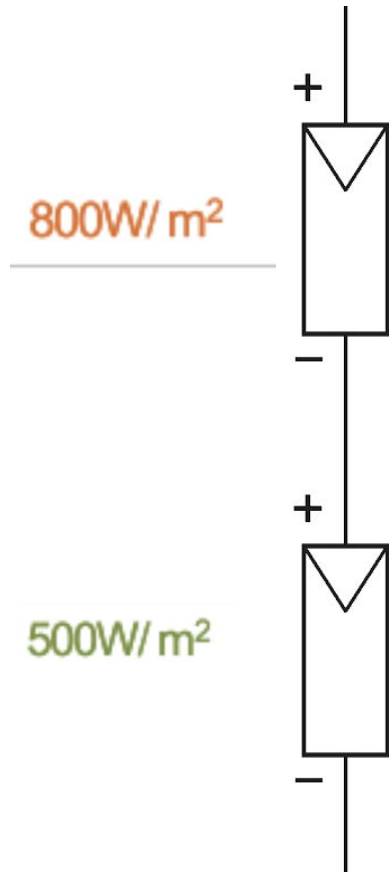
Different angle = different irradiation



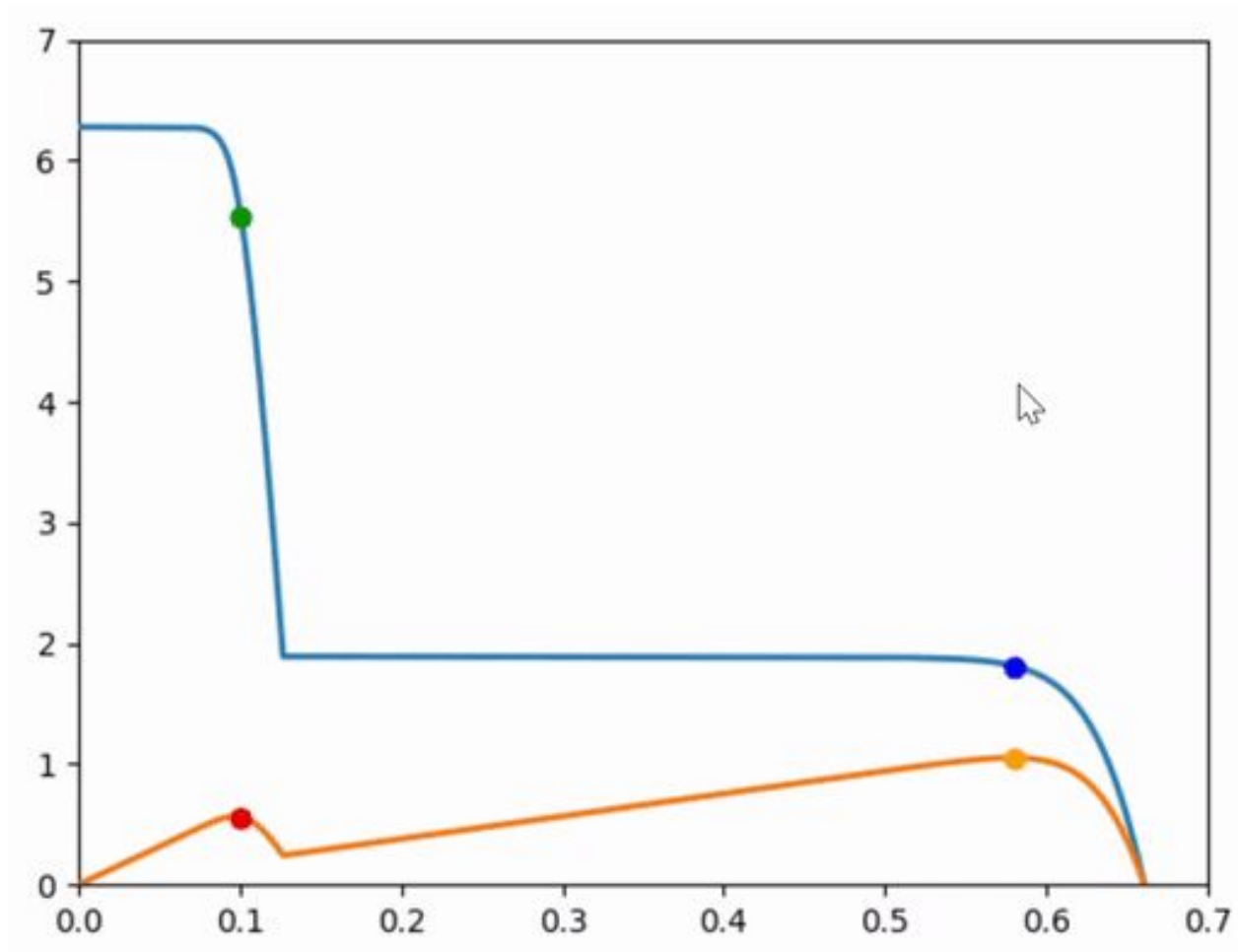
IV curve for 2 solar arrays



IV curve for series solar cell



Dynamic tracking example



Beware

Don't take Global MPPT tracking for granted!

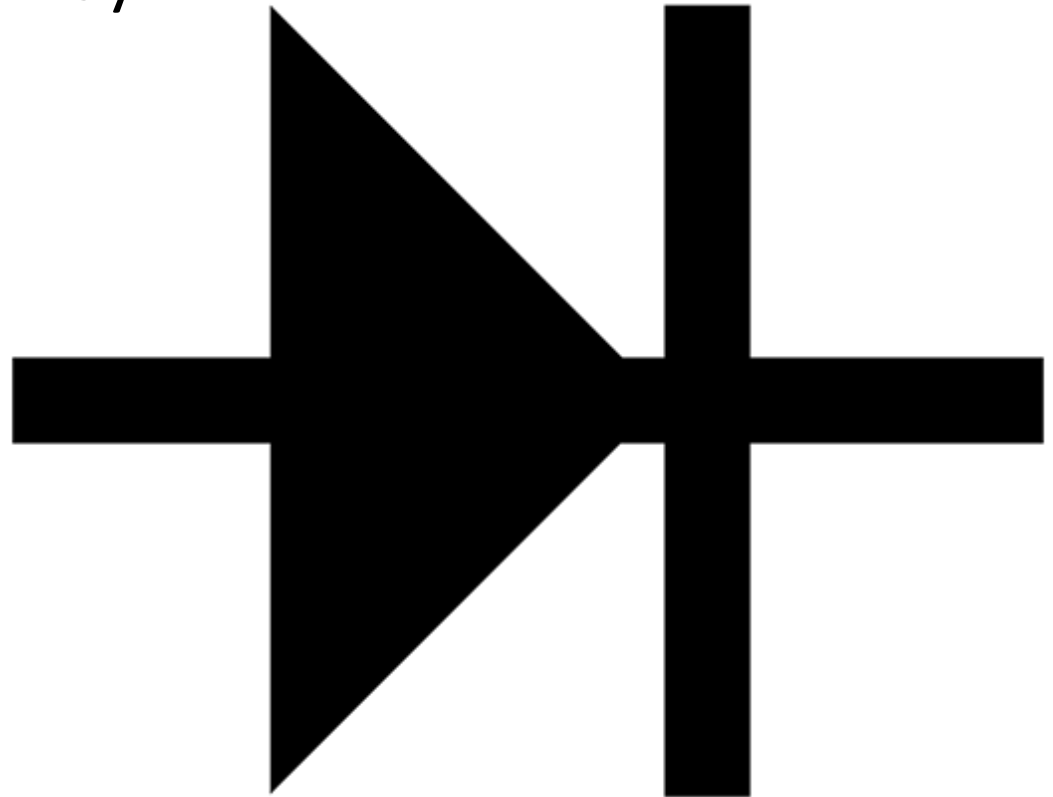
<https://youtu.be/ju50YjL202t>



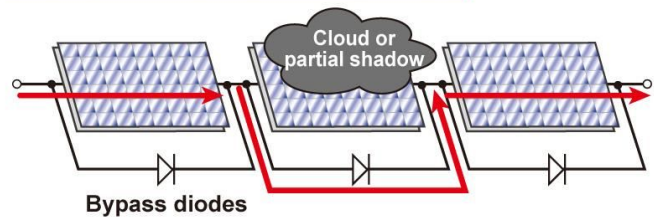
Diodes

Diodes, why?

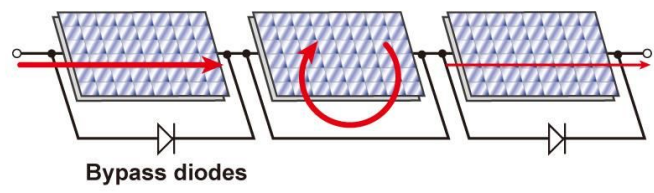
- Increasing output power of your array
- Avoiding damage to your solar array



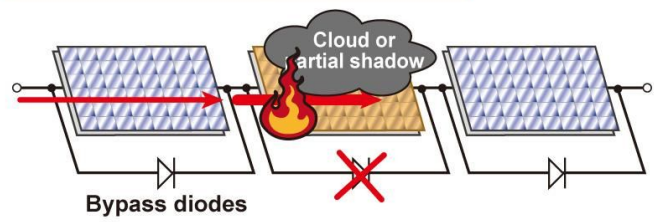
Normal reading: Current is routed around panels that are covered by shadows



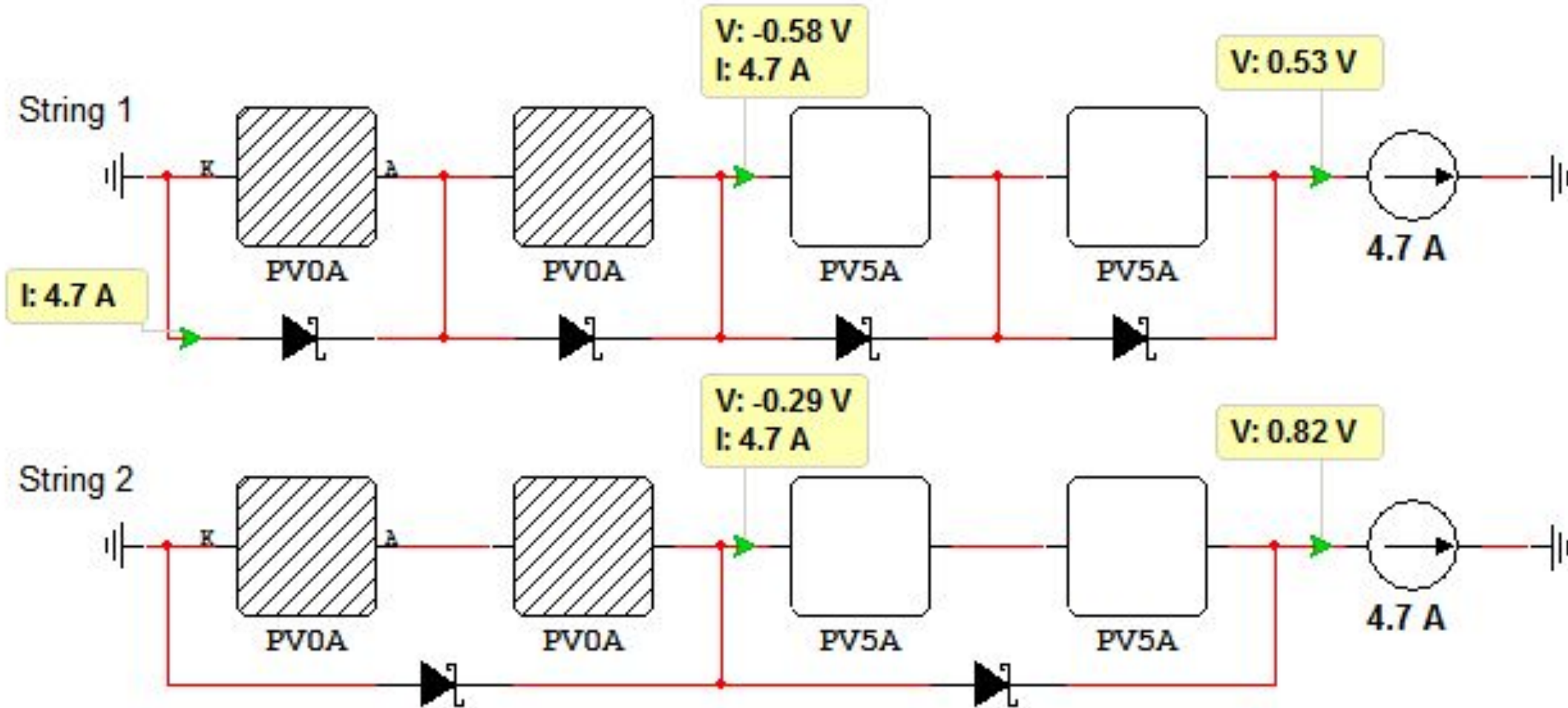
Short-circuit fault:
Generating capacity falls



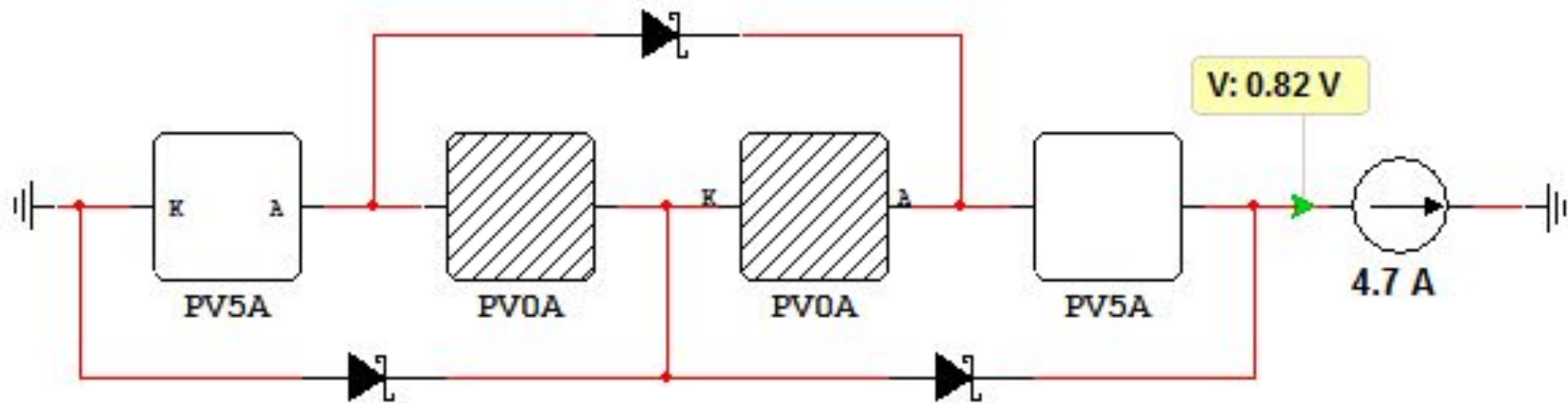
Open fault:
Potential fire



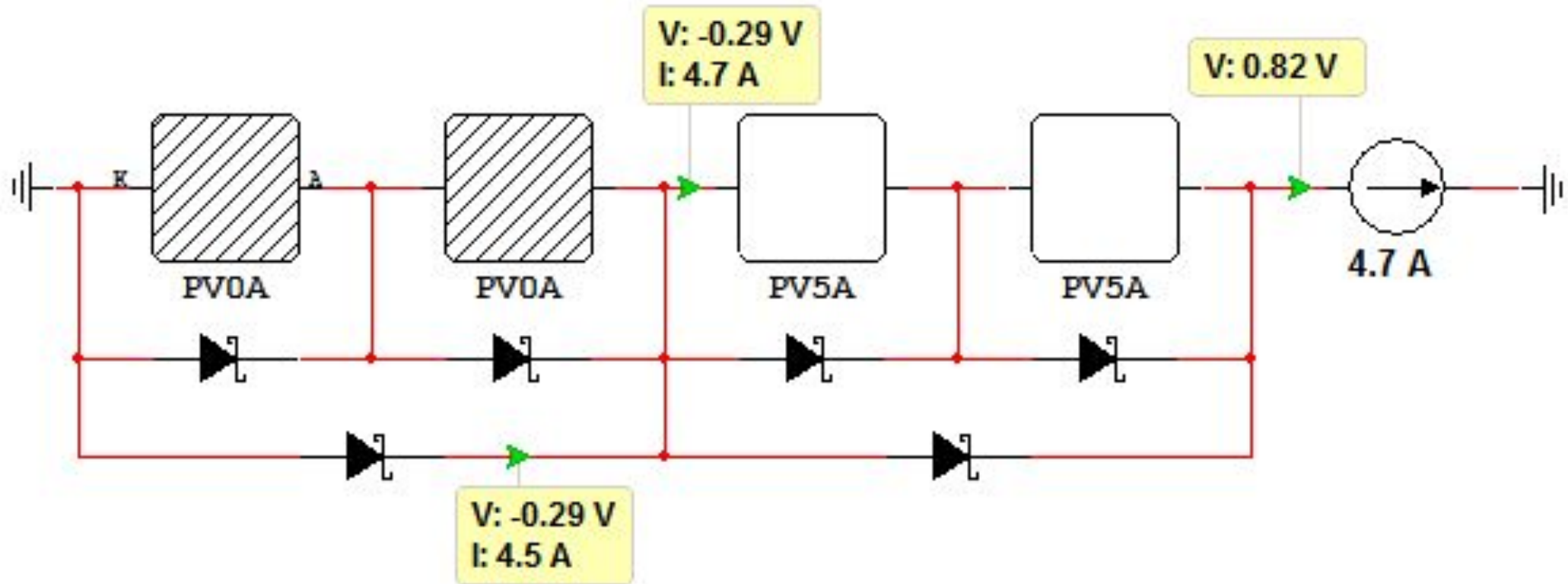
Less is better?



Less is better?



Multilevel groups

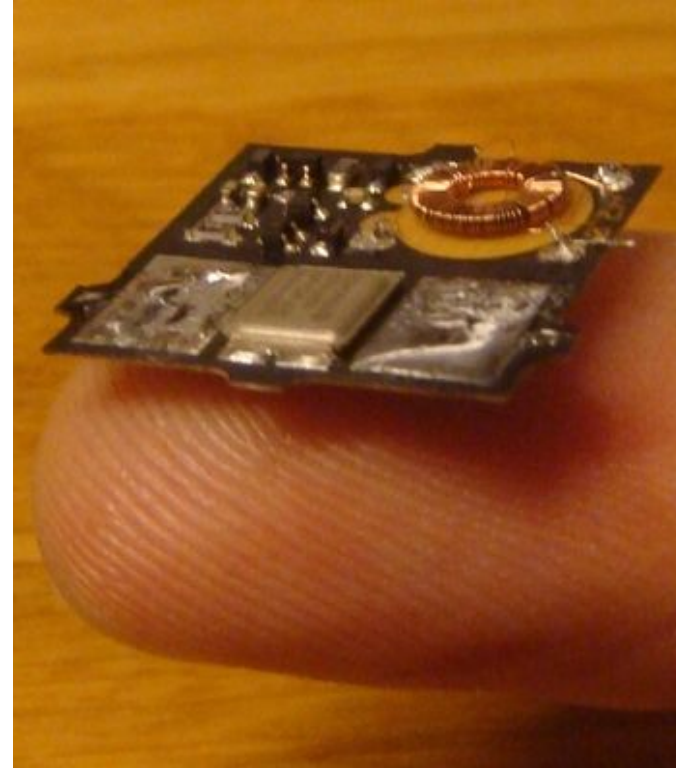


Smart diodes

First smart bypass diode

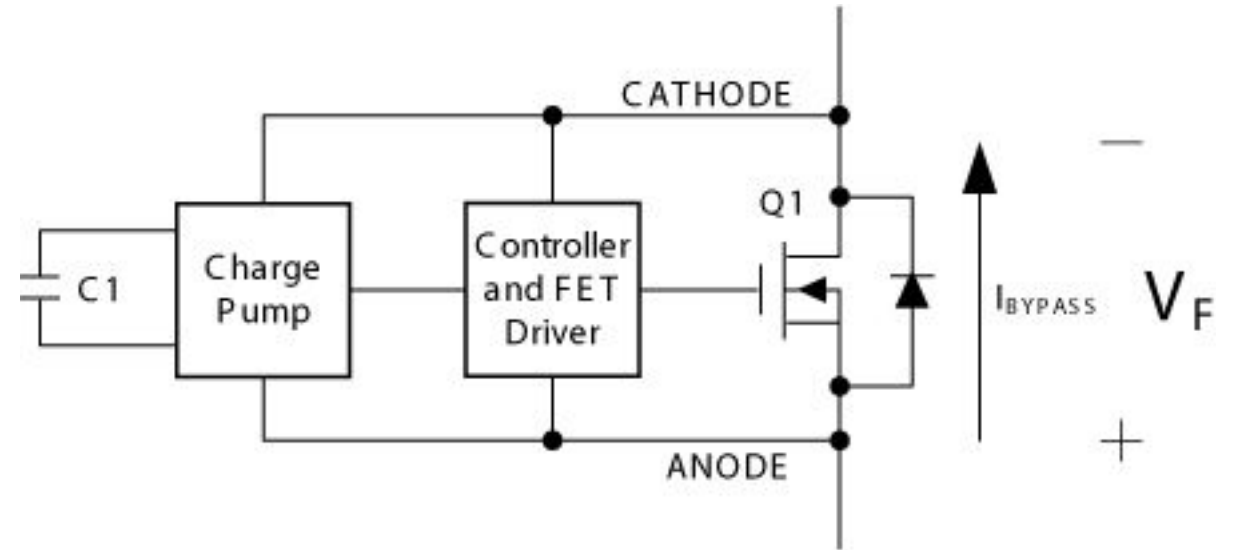
Self made smart bypass diode

Made by OKE services in 2006



Modern smart bypass diode

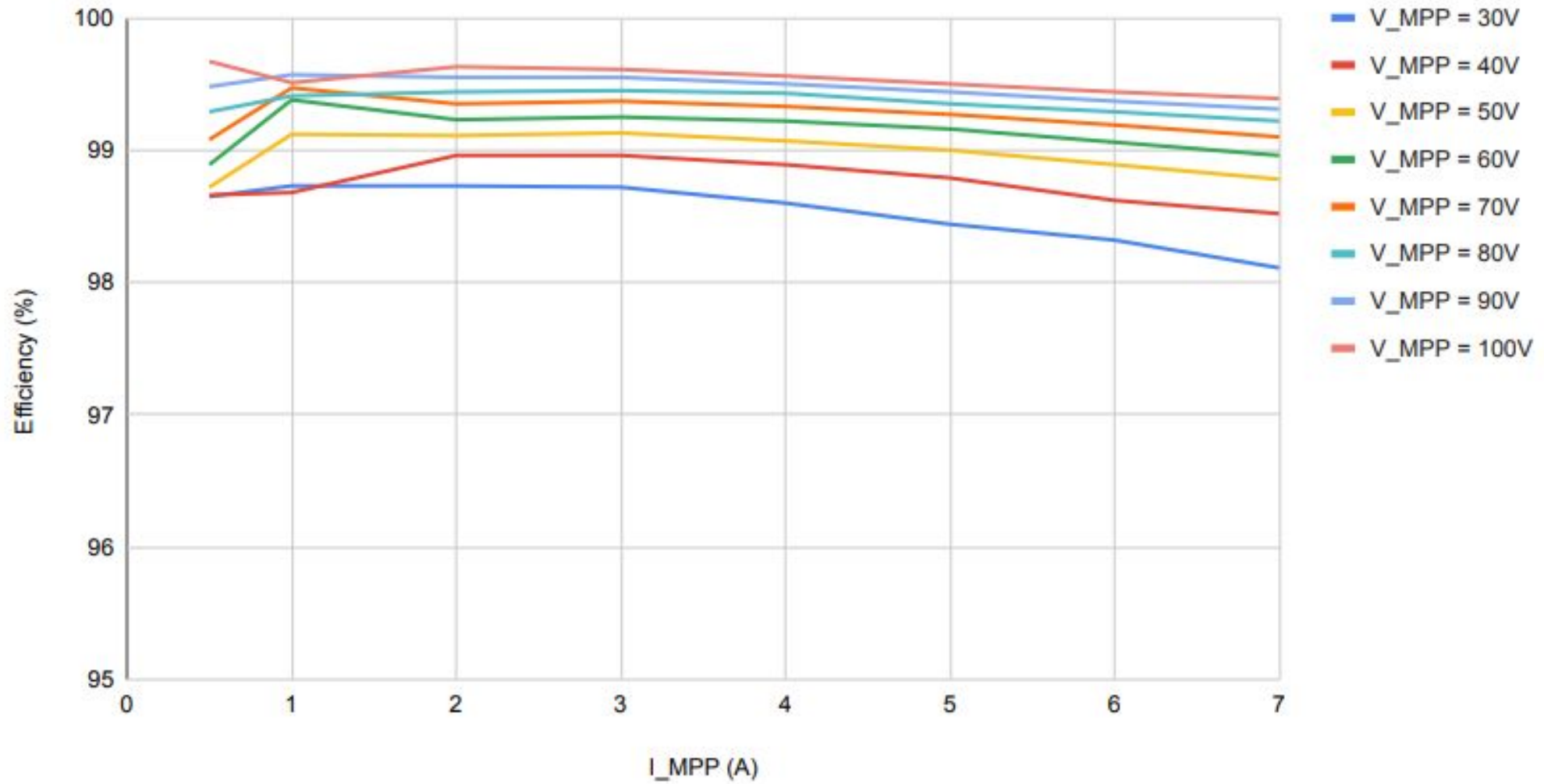
- TI SM74611
- Might confuse MPPT's



MPPT efficiency

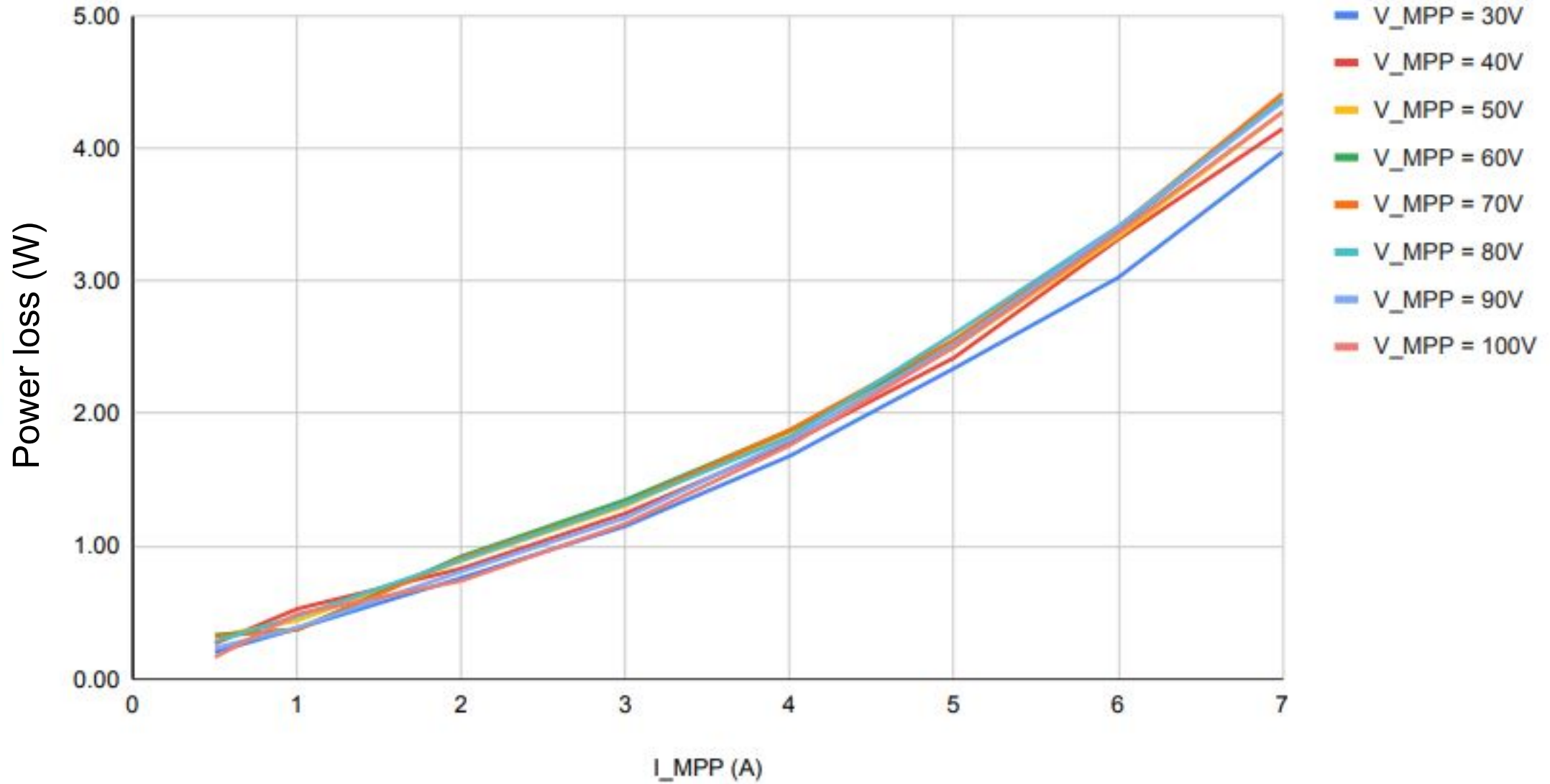
Efficiency of Elmar Solar's Best MPPT (2021)

$V_{OUT} = 120V$



Power loss of Elmar Solar's Best MPPT (2021)

$V_{OUT} = 120V$



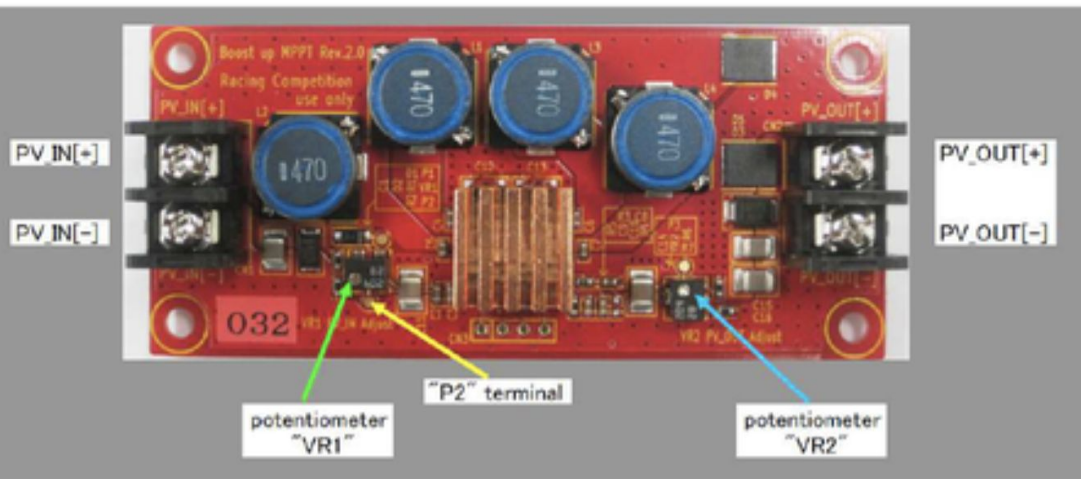
Series MPPT's

series boost MPPT's

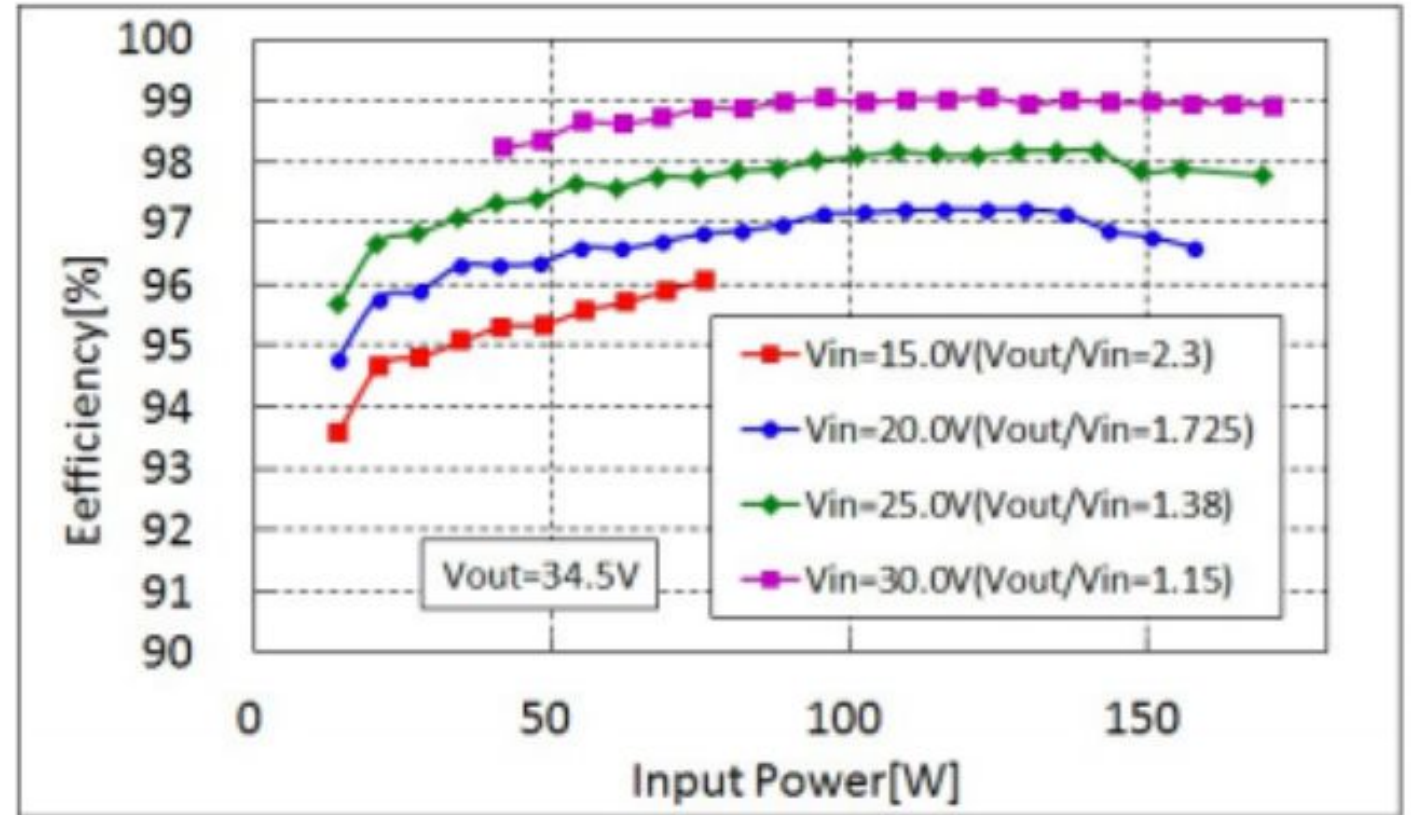
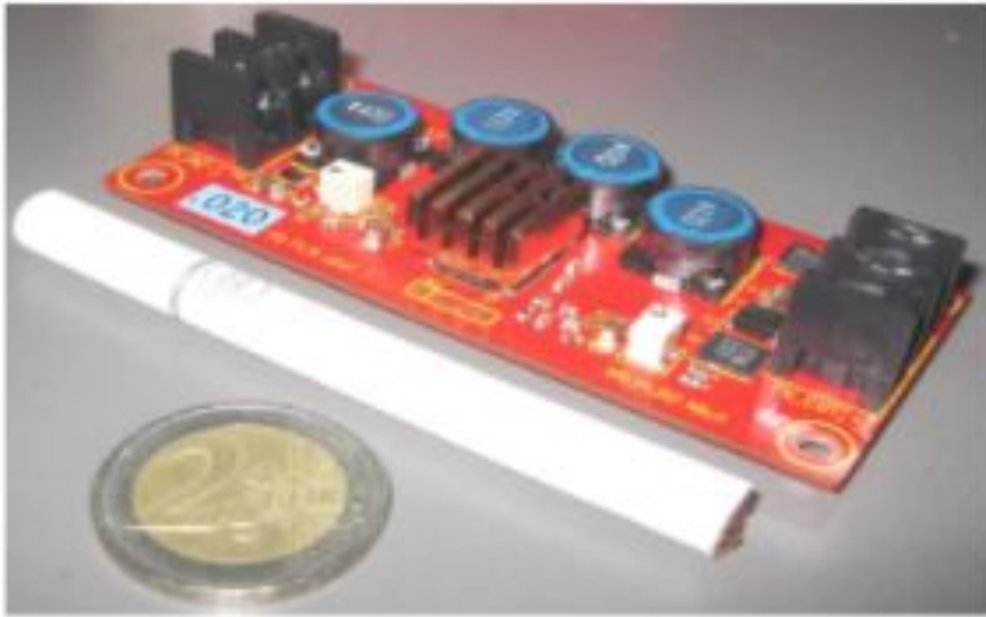
does not work very well
for compensating shaded
cells

let's see why

<https://www.st.com/en/power-management/spv1020.html>



Output Series MPPT

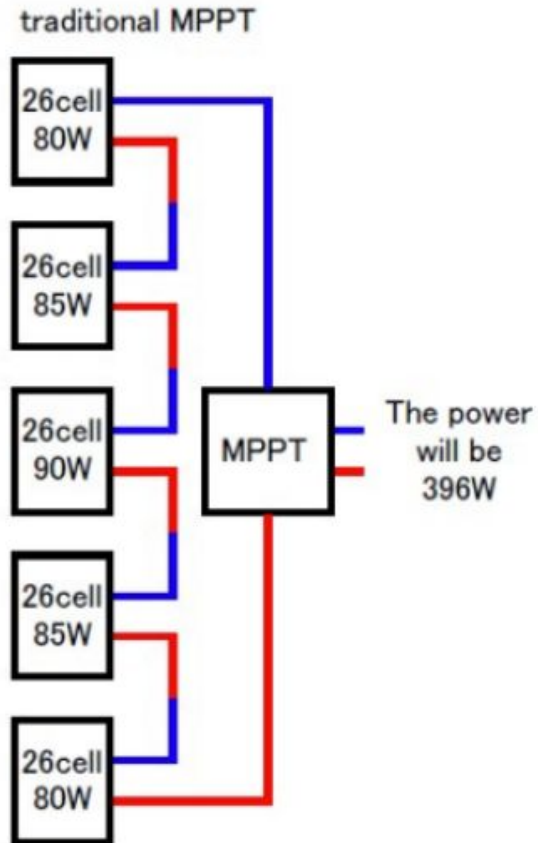


Output Series MPPT

Traditional MPPT

$$80W \times 5 \text{ modules} = 400W$$

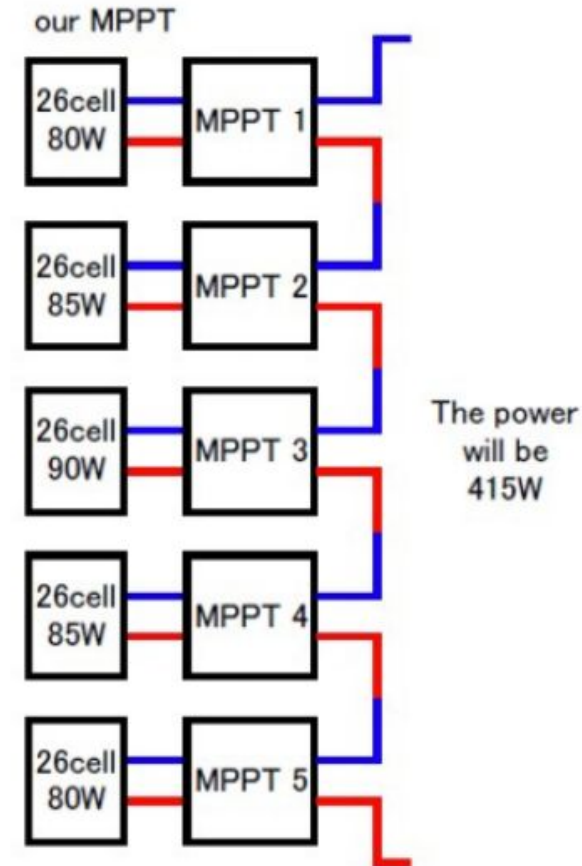
$$400W \times 99\% = 396W$$



Our MPPT

$$80W + 85W + 90W + 85W + 80W = 420W$$

$$420W \times 99\% = 415W$$

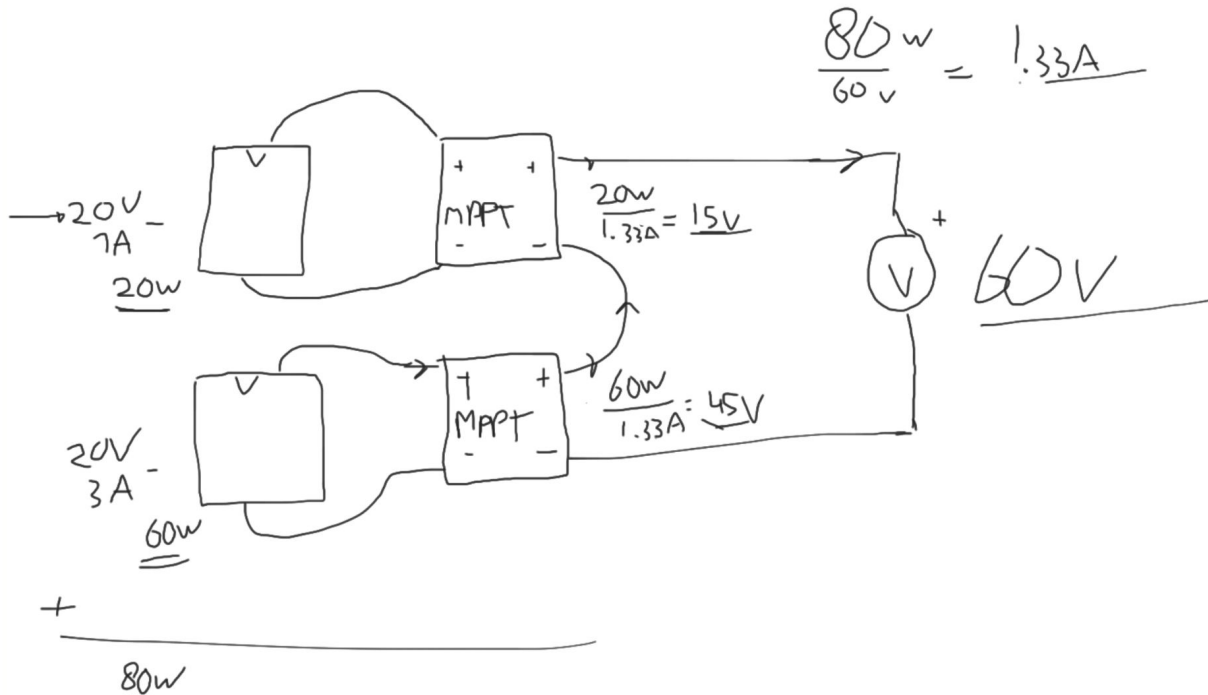


Here you can see **19W difference** which means **57W difference** if consider 3ch line

example with 2 series MPPT's and shade

top MPPT goes from 20V to 15V
so this should be a BUCK!!!

bottom MPPT goes to 45V so
this needs to be compatible
with the MAX output voltage
spec!!!



Output Series MPPT

Works well for solving small differences like curvature

Does **NOT** work well for compensating shaded arrays

Will still go in **BYPASS**

TOKAI PAPER

look for:

Buck-Boost-Type MPPT Circuit Suitable for Vehicle-Mounted Photovoltaic Power Generation

Fumihisa Kano^{*,**a}, Member

Yuji Kasai^{***}, Member

Hideki Kimura^{****}, Member

Kouhei Sagawa^{****}, Non-member

Junnosuke Haruna^{*}, Member

Hirohito Funato^{*}, Senior Member

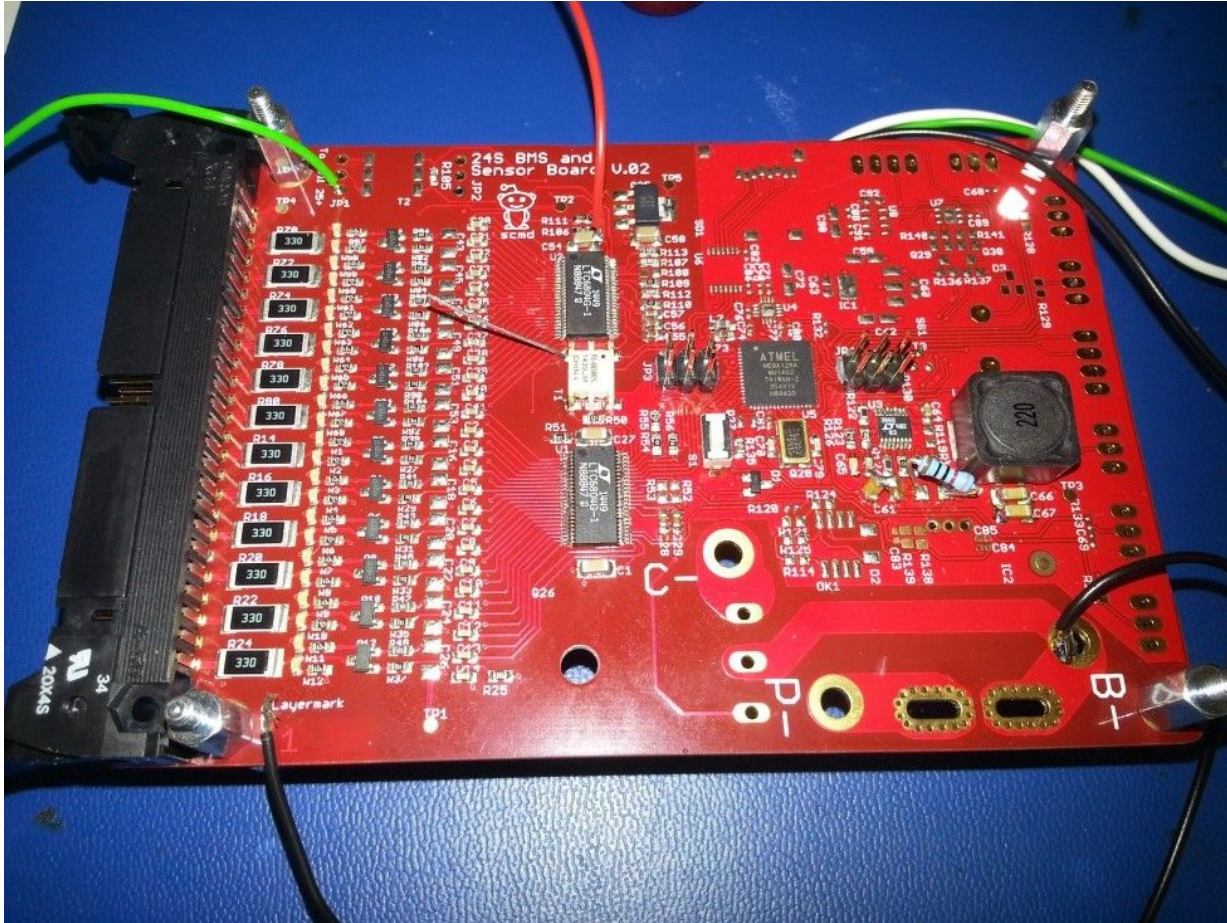
DMPPT's

SABINE

Solar array balancing



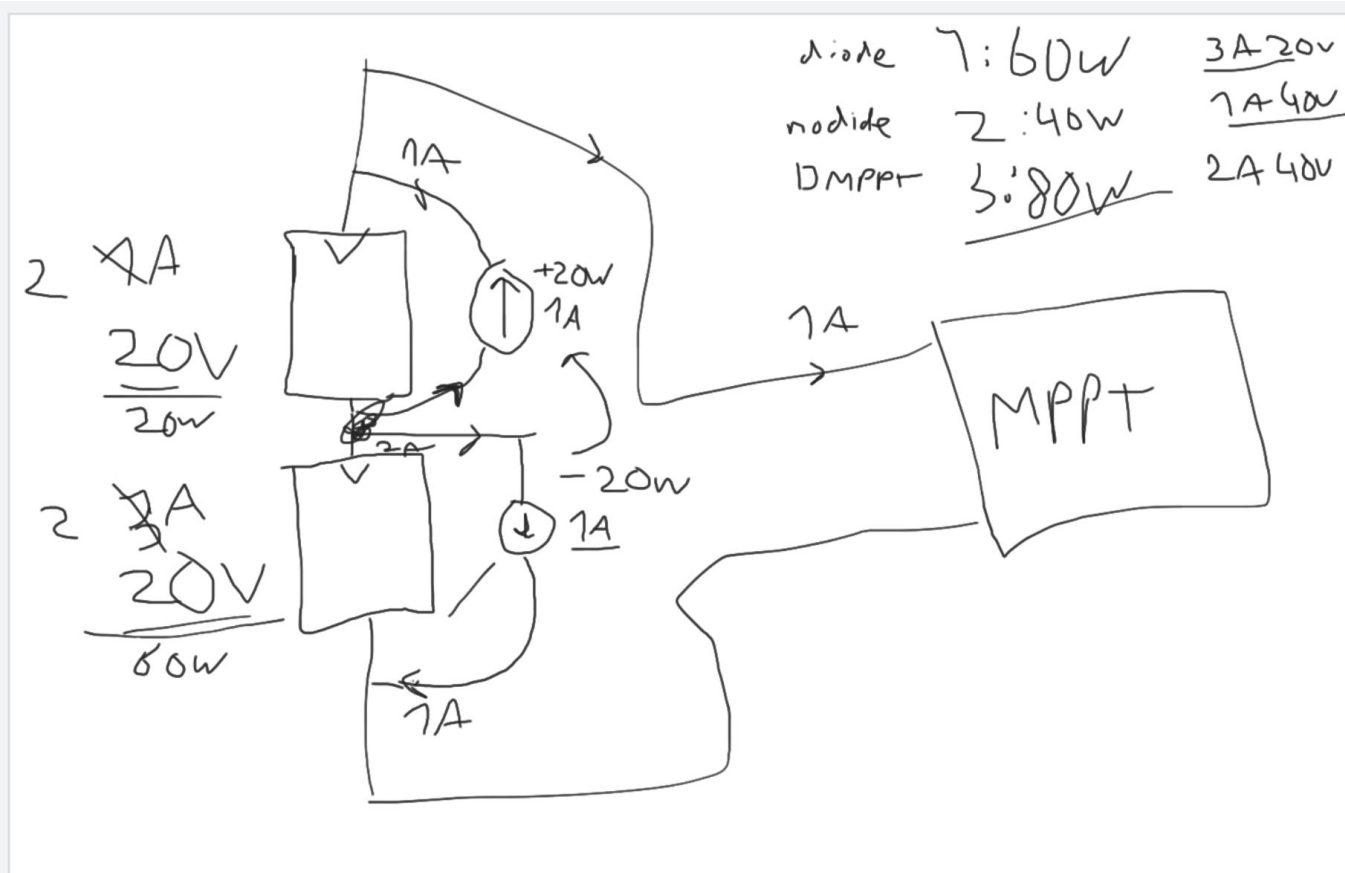
Voltage monitoring



a li-ion voltage monitor system designed for 2.5-4.2V li-ion series cells can also be used to monitor larger strings of solar cells.

Make groups of 5 or 6 solar cells to be within the measurement range.

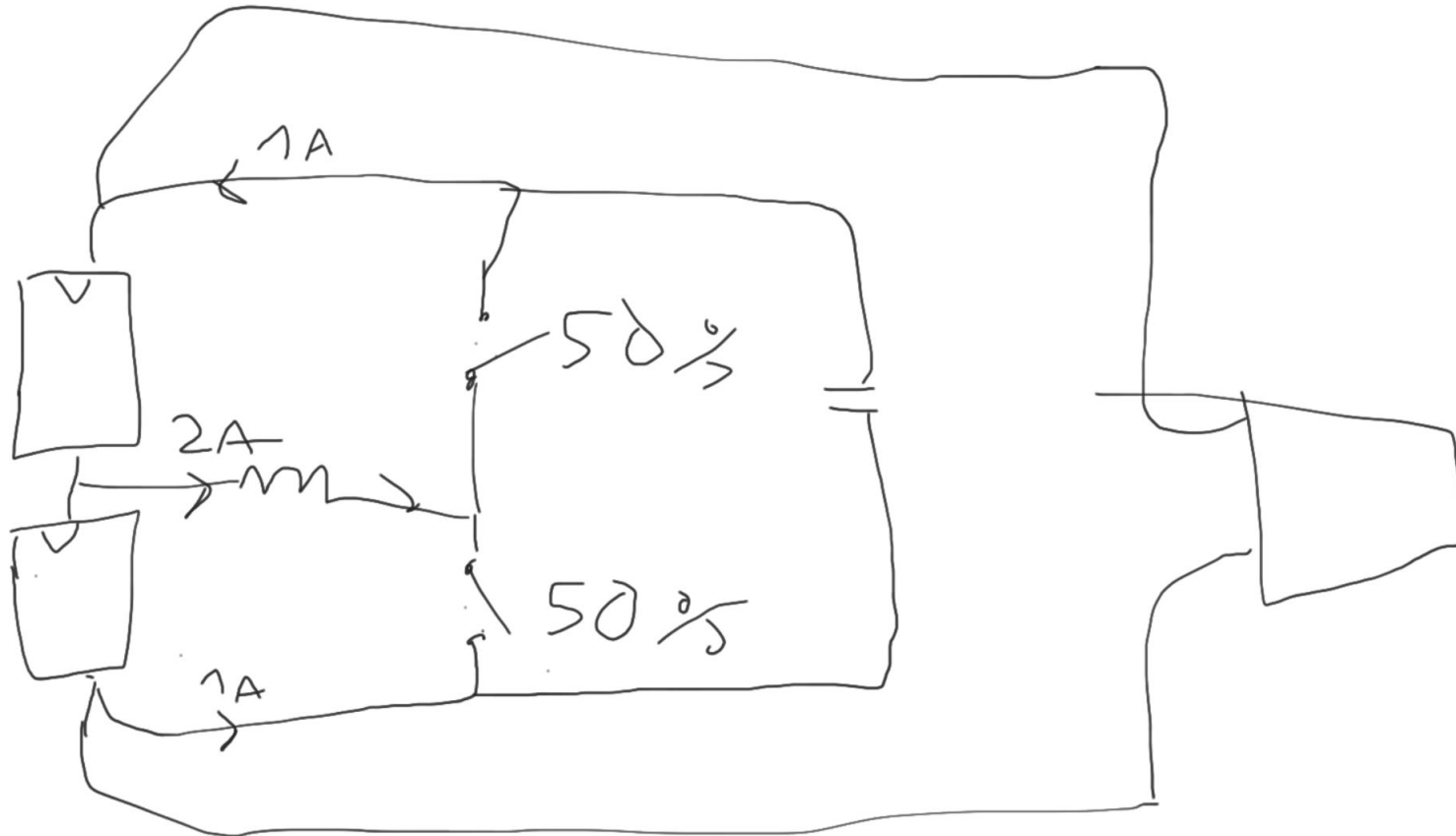
The idea



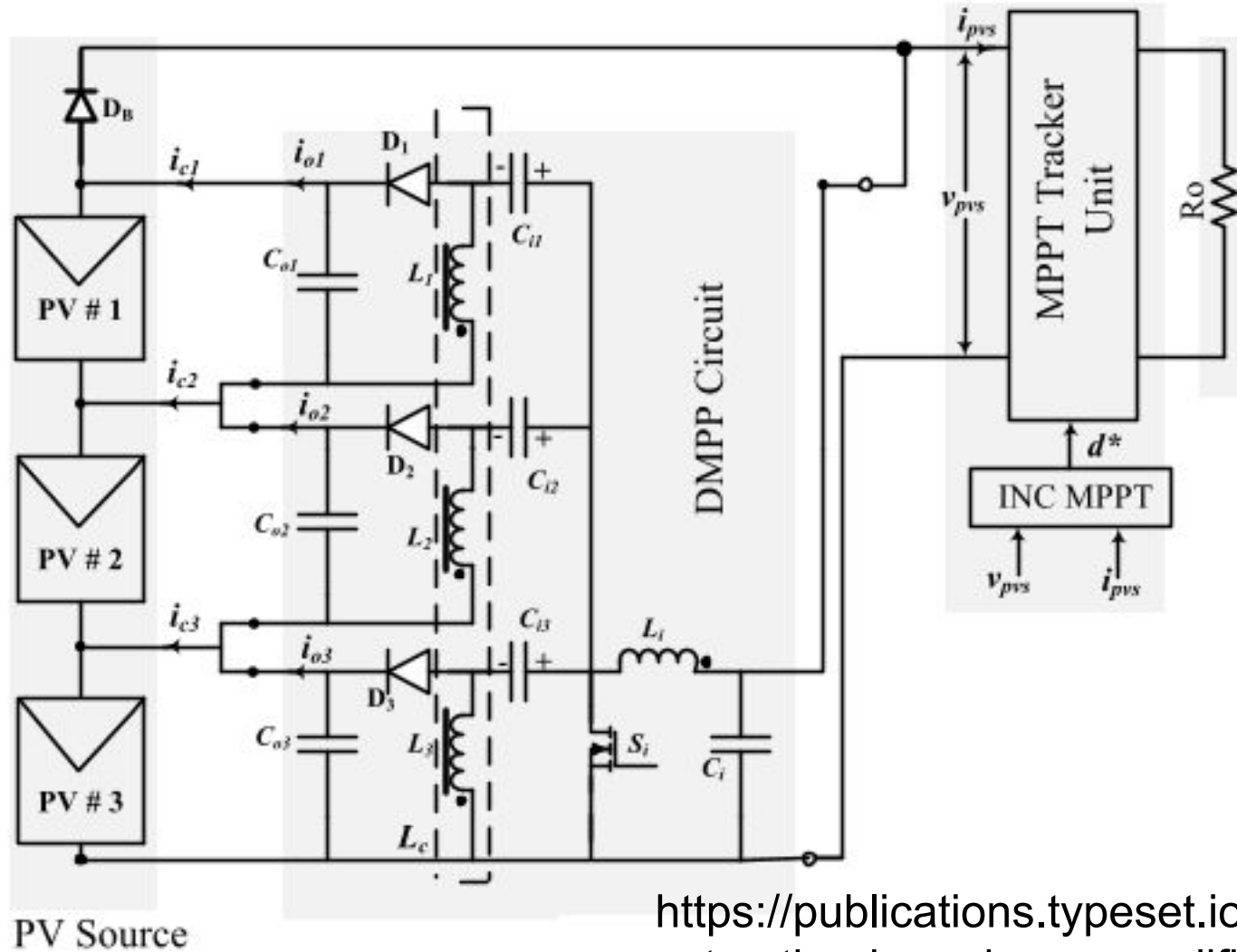
taking current from strong cells and moving that current to weaker cells to make them all have equal

1 way of doing this: inductive

basically by putting a bidirectional buck or boost converter in parallel to transfer "current"



DMMPT example / paper



<https://publications.typeset.io/publication/distributed-pv-power-extraction-based-on-a-modified-interleaved/figure/fig-3-proposed-interleaved-sepic-based-dmppt-configuration.png>

Buck string optimizer

