Modeling Electrical Shading Effects in PVsyst

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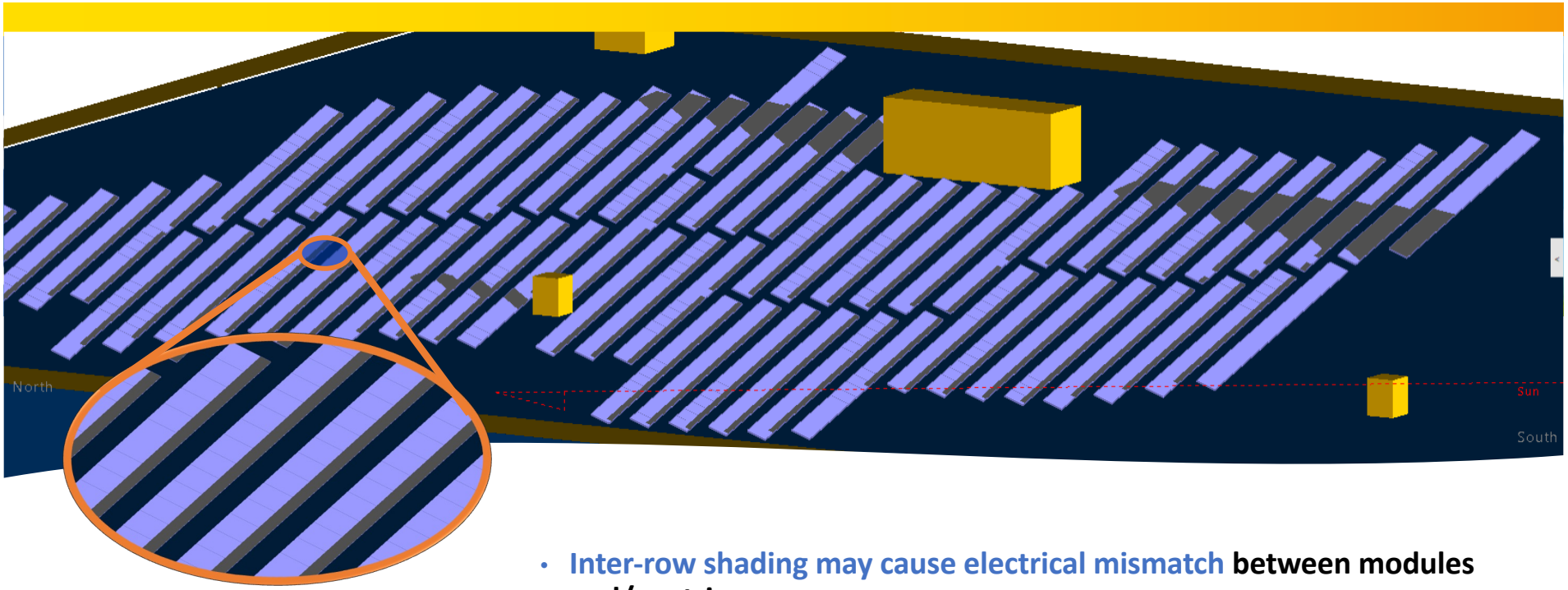


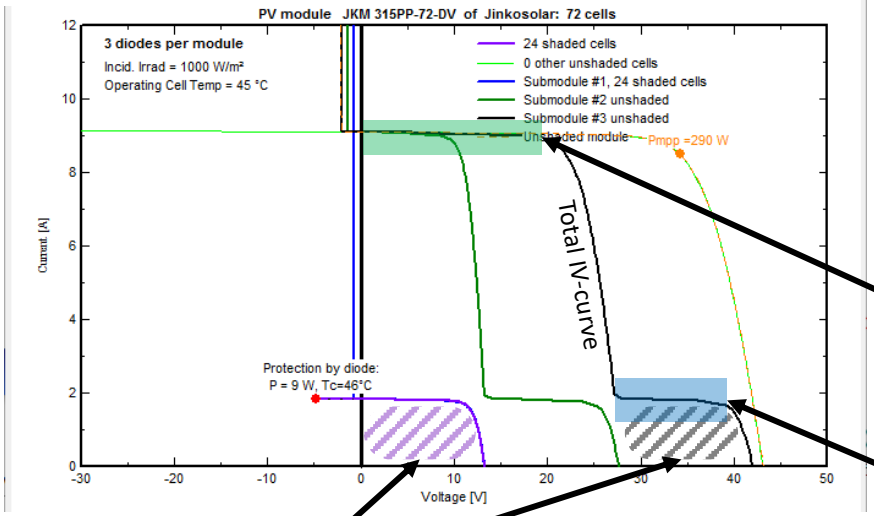
Overview

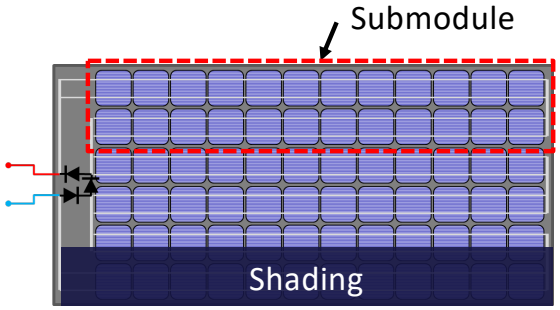
- Inter-row shading may cause electrical mismatch between modules and/or strings
- But this mismatch can be reduced by optimizers
- We model the impact on electrical shading losses for different fixed-tilt row-based system layouts and optimizer choices.

Electrical effects of partial shading 1/2

- **Shading on a single module**

Example: 1 submodule partially shaded





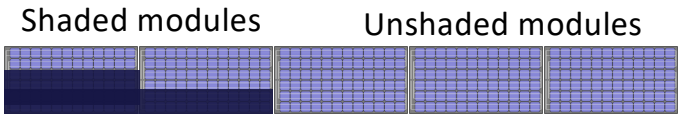
In this range, the shaded submodule's bypass diode is activated

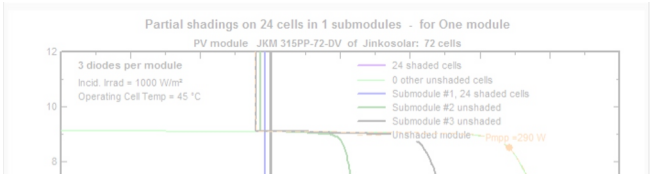
In this range, the shaded submodule limits the current

Diffuse fraction

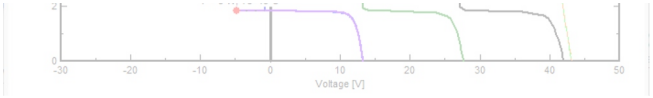
Electrical effects of partial shading 2/2

- **Mismatch among modules**

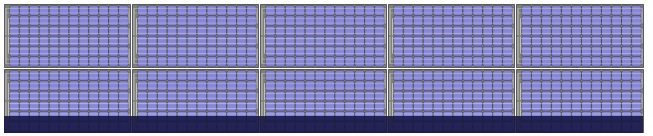


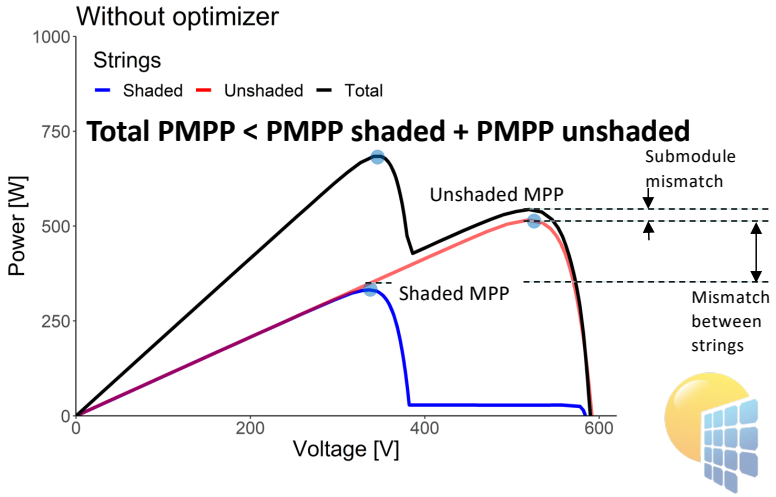


Same principle as submodules !
(series connection)

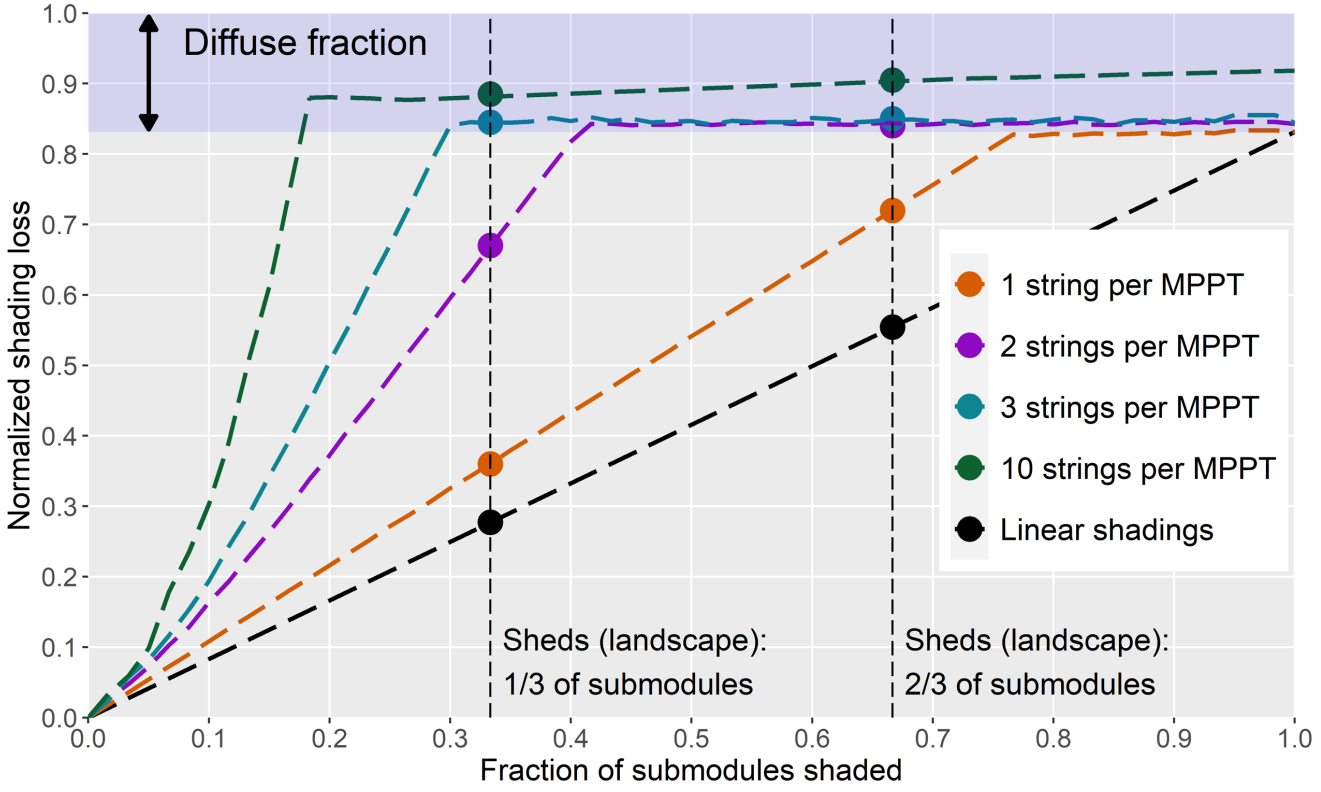


- **Mismatch among strings**





Shading loss normalized to a single string's generation



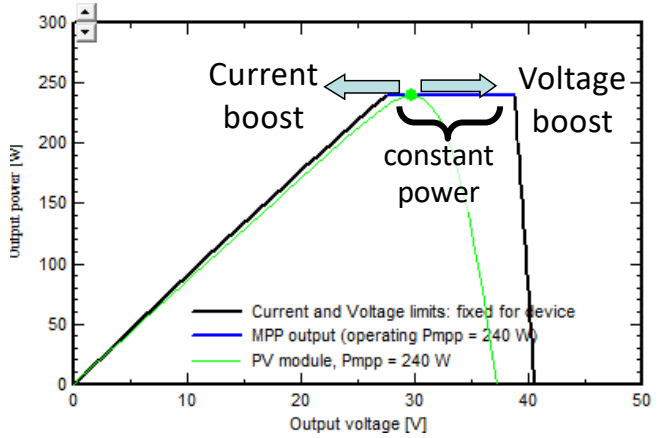
Optimizers

- **Allow operating point to be displaced while keeping the MPP power**

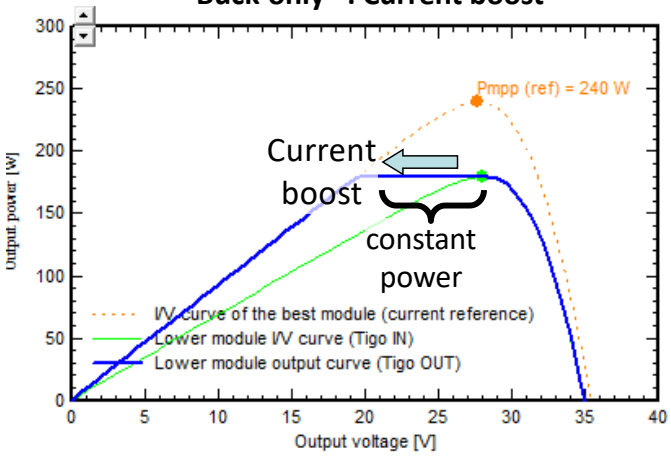
→ **Extends MPP to a range**

- **String optimizers (usually current boost)**
- **Module optimizers:**
  - Full optimizers (voltage and current boost)
  - Buck-only (only current boost)
- **Sub-module optimizers (usually current boost)**

Full optimizer (Buck-Boost) Current & Voltage boost

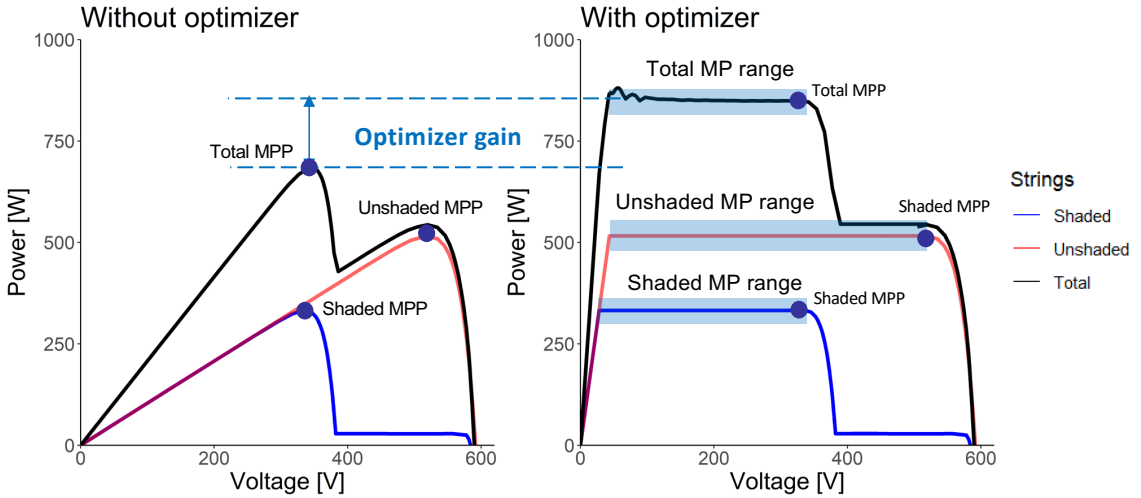


"Buck-only" : Current boost



Optimizers and shadings

- **By extending the MPP, mismatch between modules and/or strings can be mitigated.**
  - Example:
    - 1 shaded string in parallel with 1 unshaded string
    - PV curve comparison with and without module optimizer



String optimizers will work similarly for regular inter-row shadings

Goal of the shading study

1. **Understand the electrical effect of shadings on different system layouts and optimizer setups**

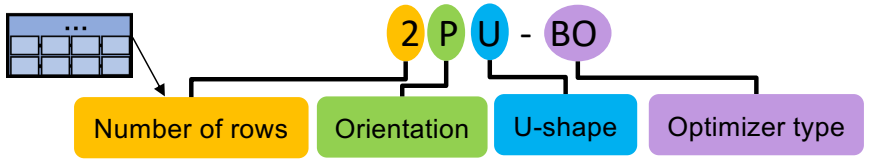
2. **Describe how to best model these effects in PVsyst (detailed vs. simplified model)**

- **First part of study presented at PVSEC 2021**

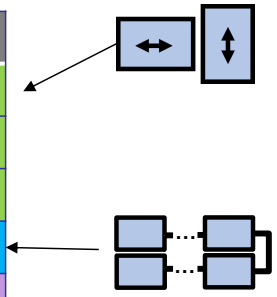
  38th European PV Solar Energy Conference (PVSEC 2021), "Analysis of Electrical Shading Effects in PV Systems", M. Oliosi, A. Mermoud and B. Wittmer

Setup for the study

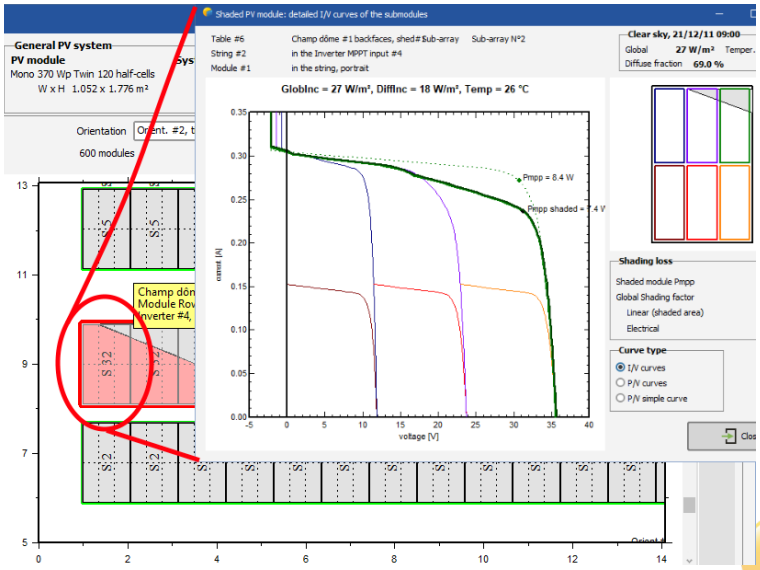
- **Setups studied abbreviated as**



Abbrev.	Meaning
L	Landscape
P	Portrait
T	Half-cut in portrait
U	U-shape connection
BO	Buck-only optimizer
FO	Full optimizer
SMO	Submodule optimizer
SO	String optimizer

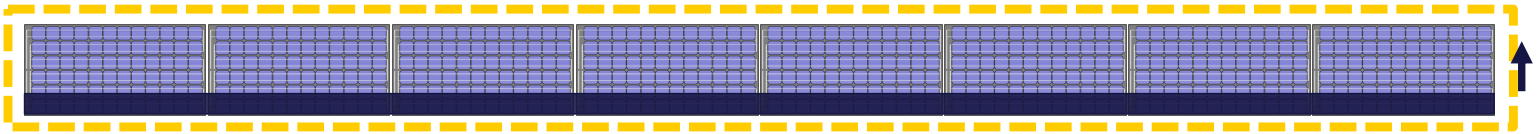


- **Reference: "module layout" detailed IV-curve calculation**



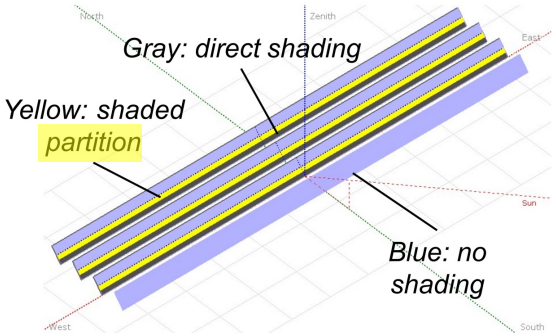
Simplified model

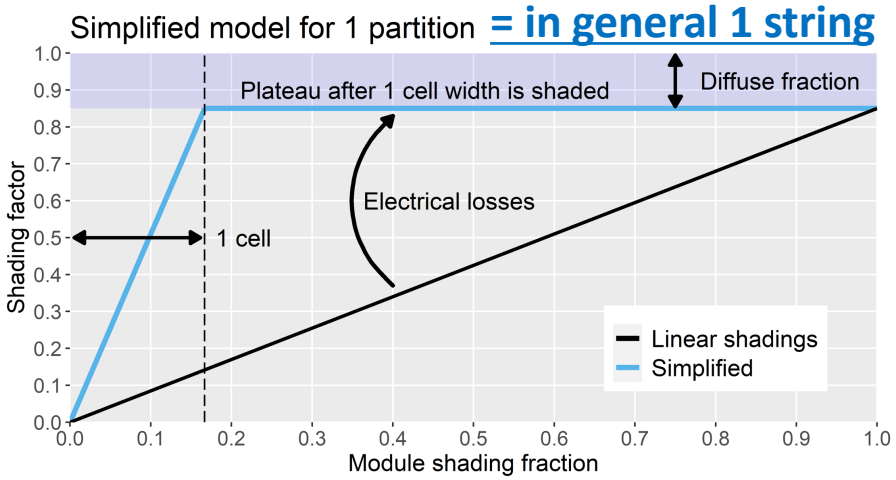
- **Designed for <u>regular interrow shading conditions</u> and <u>> 1 string/MPPT</u>**



Shadow growth (8 sub-modules get shaded at a time)

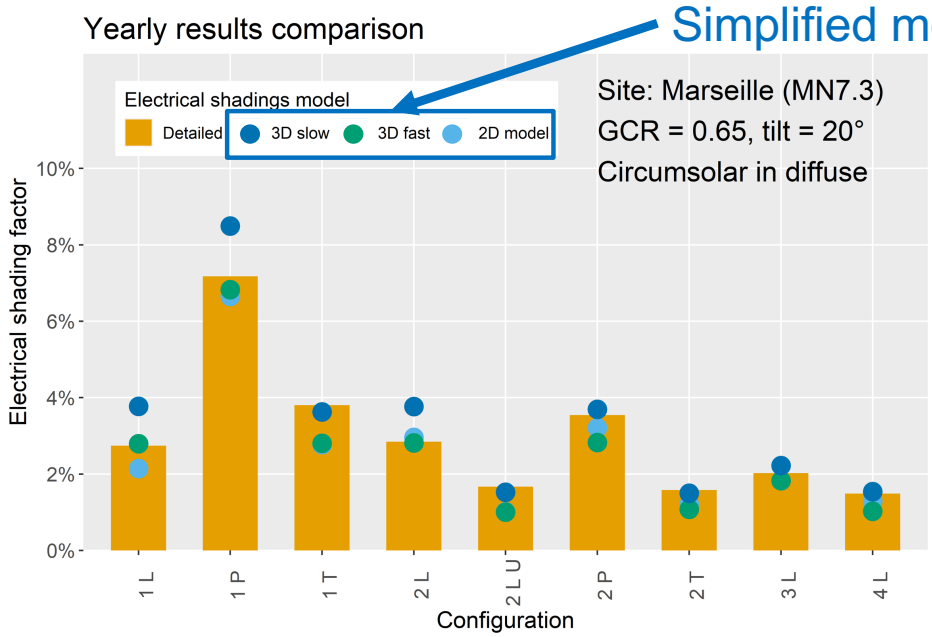
- Step-like behavior
- Parameter: # of partitions





PVSEC 2021 results

- **Only layout, no optimizers**



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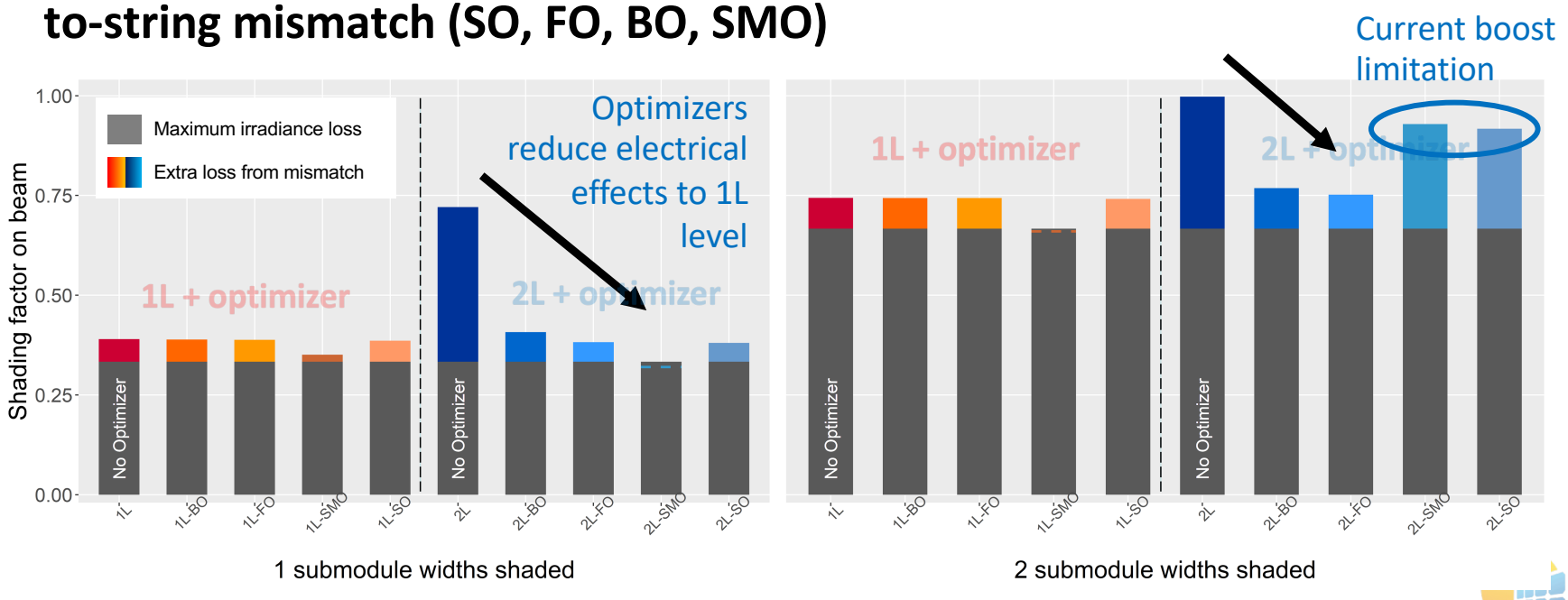
SO	String optimizer

Adjusted partitioning for the simplified model

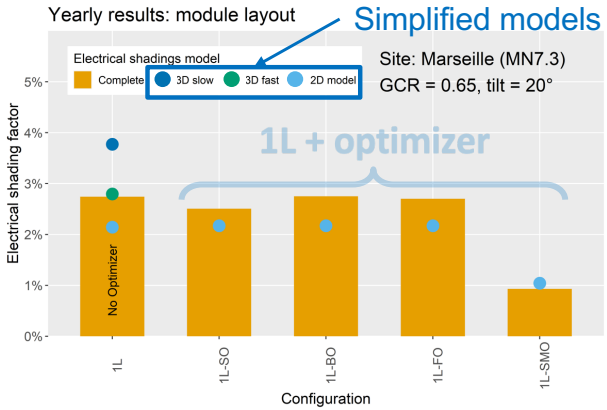
- ***1L***: 2 partitions in height.
- ***xL***: x partitions in height.
- ***xLU***: 2x partitions in height.
- ***xP***: x partitions in height.
- ***xT***: 2x partitions in height.

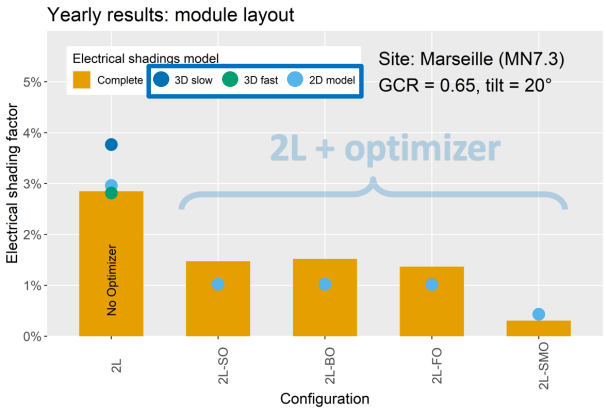
Optimizer results

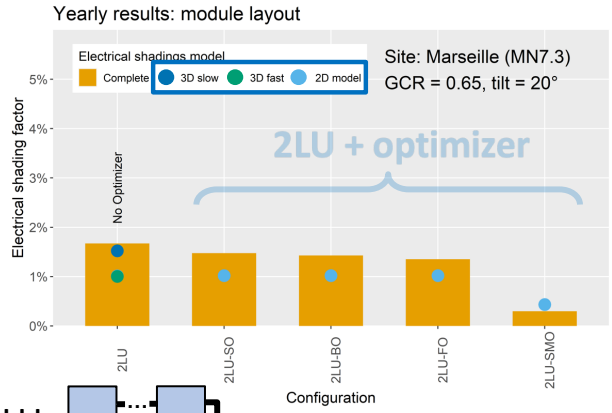
- **Optimizers help recover the submodule mismatch (SMO) or the string-to-string mismatch (SO, FO, BO, SMO)**

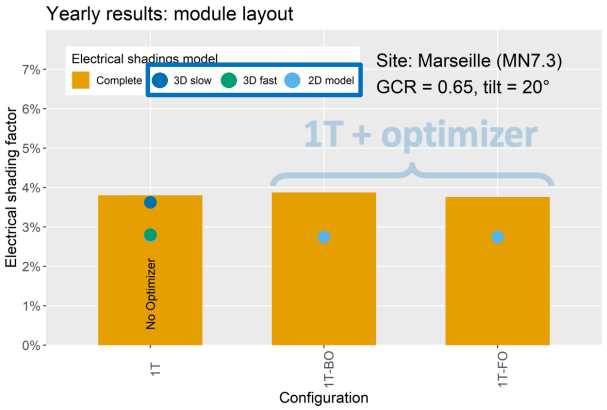


Optimizers and simplified model

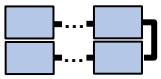








2LU:



Case	Number of partitions
1L-BO	2
1L-FO	2
1L-SMO	3
1L-SO	2
2L(U)-BO	4
2L(U)-FO	4
2L(U)-SMO	6
2L(U)-SO	4
1T-BO	2
1T-FO	2

Conclusion

- **Optimizers mitigate the mismatch losses due to shadings.**

- **Depending on expected shadings and layout, some optimizers are more effective choices than others**
  - Module and string optimizers can mitigate the mismatch between strings
  - Submodule optimizers can also mitigate the mismatch between submodules

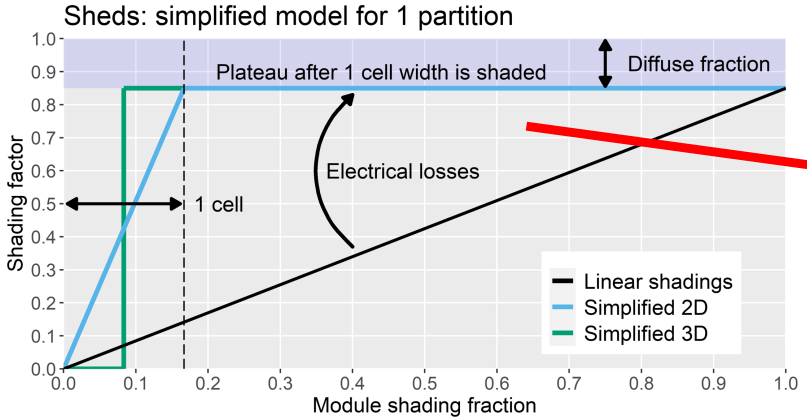
  NB: inverter and optimizer limits (current or voltage) are very important. These have improved over the years.

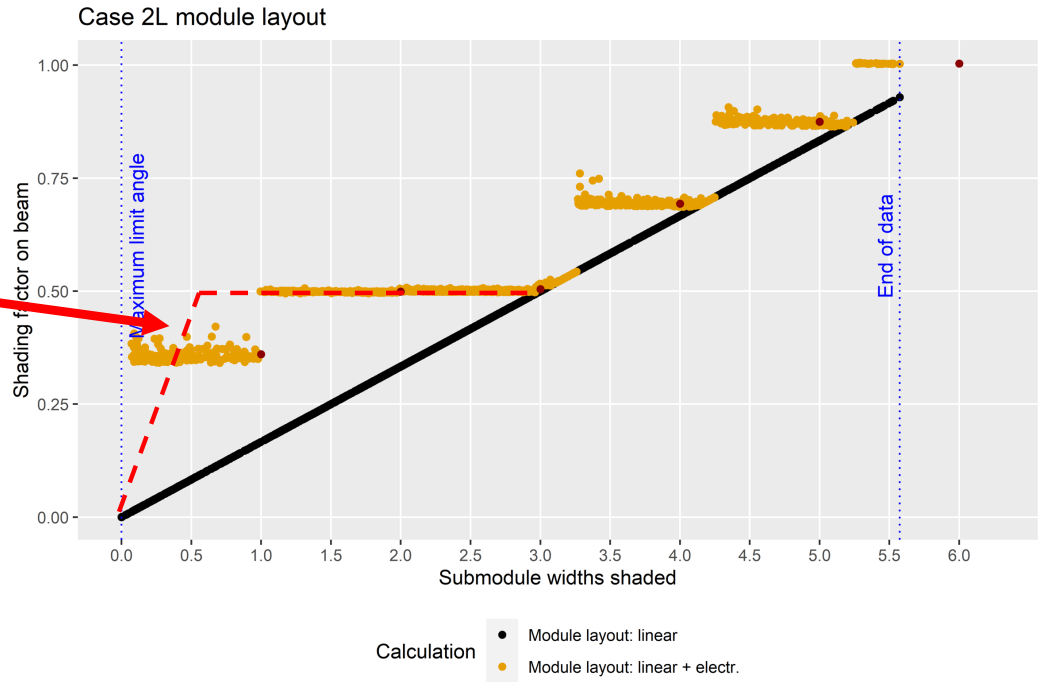
- **PVsyst simplified model can model most cases ! ➔ faster simulation.**

References

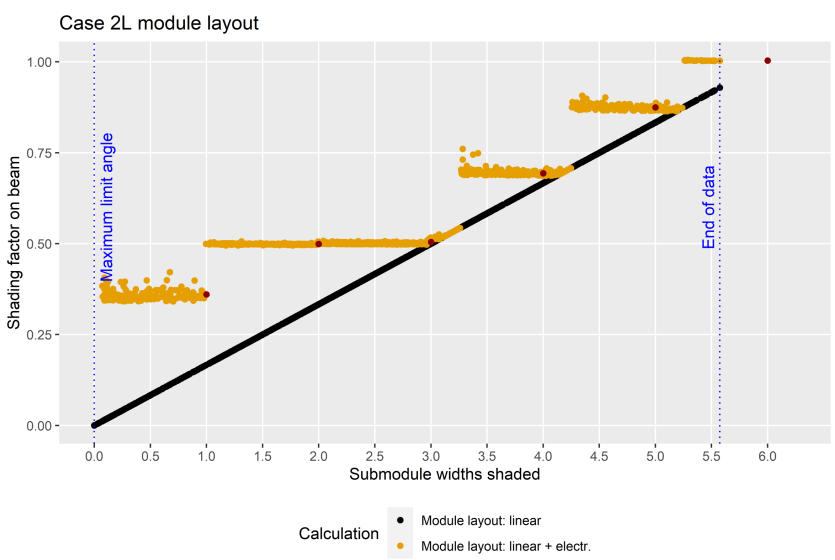
- 38th European PV Solar Energy Conference (PVSEC 2021), “Analysis of Electrical Shading Effects in PV Systems”, M. Oliosi, A. Mermoud and B. Wittmer
- 8th PV Performance Modeling Workshop (PVPMC 2017), “Modelling PV Power Optimizers with PVsyst for Row-Based PV Installations”, A. Mermoud and B. Wittmer

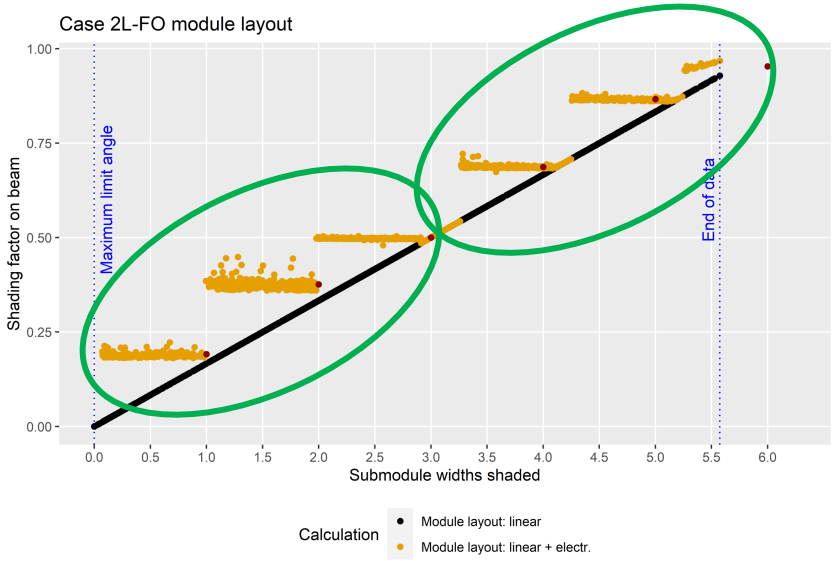
«Staircase» shading plots *vs* simplified model



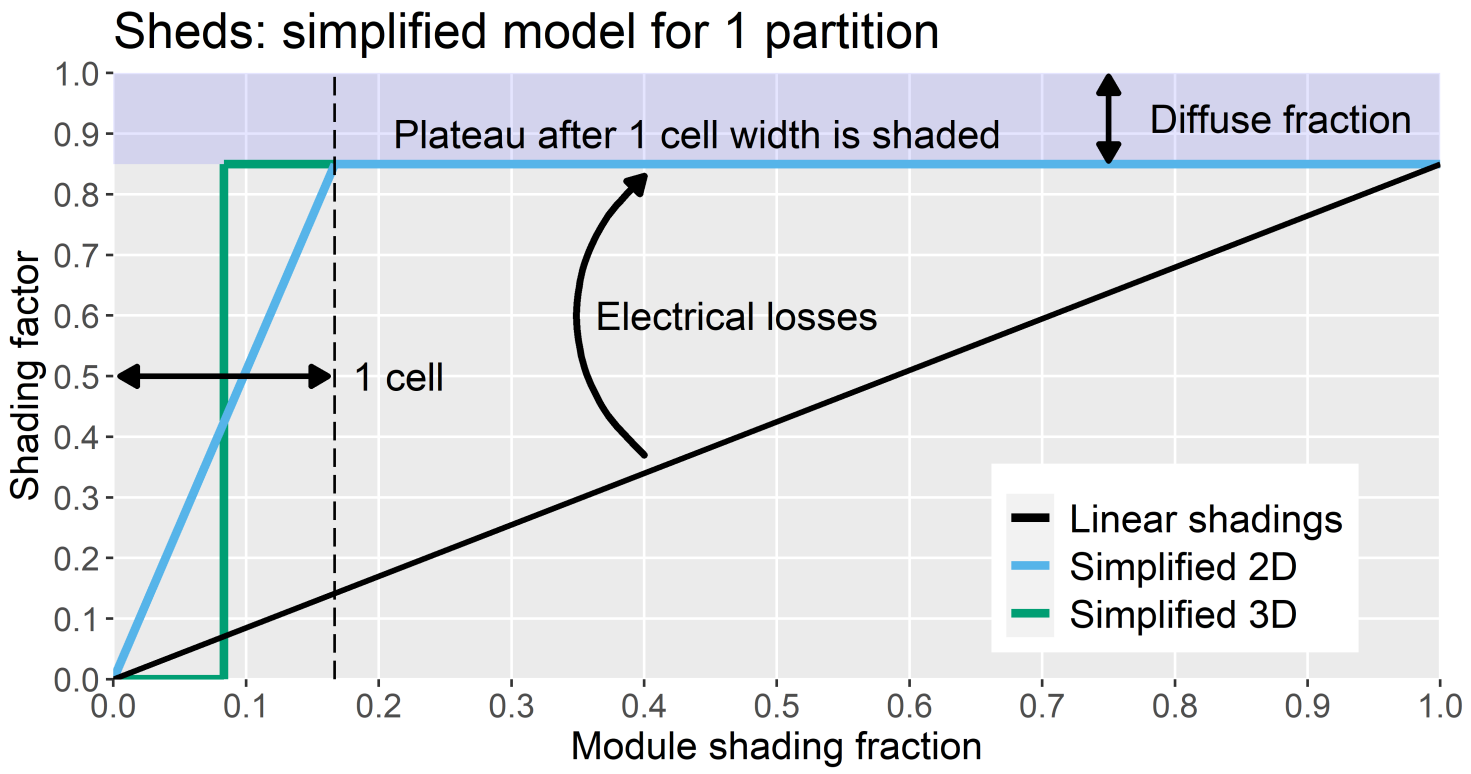


«Staircase» shading plots – case 2L





Simplified model: 2D vs 3D



Cell shading