Subtask 2.1 Performance and Reliability of FPV – Chapter 2 FPV Energy Yield

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EUPVSEC Parallel Event 2024

Yield Assesment of FPV Systems

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Thermal losses – and the mythical U-value

- Early studies clamed large increase in performance
- Why do we talk about this «U-value»?
- U-value not uniquely defined!

$$T_m = T_a + \frac{q_{sun}(1 - \text{ module efficiency})}{U_{conv}}$$ or $$T_m = T_a + \frac{q_{sun}}{U}$$ or...

The ability to exchange heat with the surroundings

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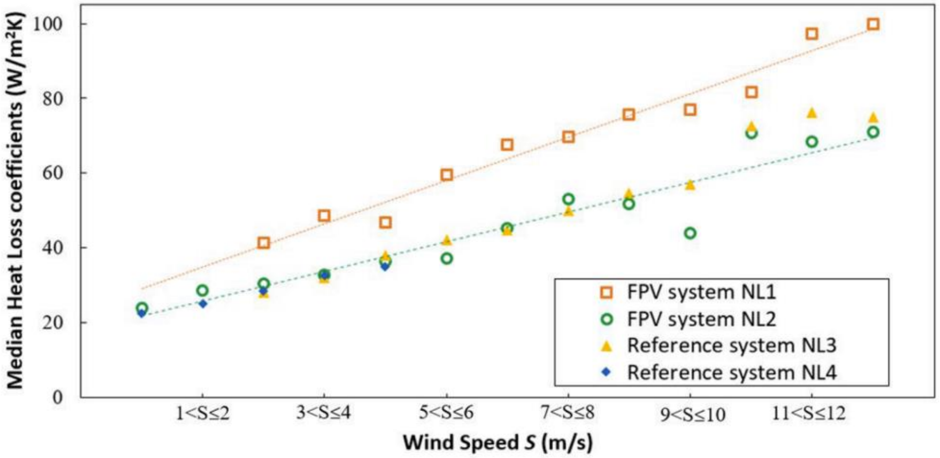
Thermal losses – and the mythical U-value

- The challenge of single U-value
  - Clear wind dependency → $U = U_0 + U_1 WS$.
  - Empirical value influenced by local conditions



Ideal world: unique value per FPV system type, applied generically
Real world: empirical value incorporating factors such as wind direction, humidity, cloudiness, local topography, size of the plant, and placement of the sensors

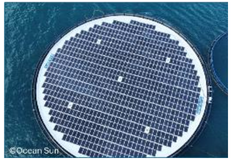
H. Liu, et al. *Progress in Photovoltaics*, vol. 26, no. 12, pp. 957–967, Dec. 2018, doi: 10.1002/pip.3039.
M. Dörenkämper, et al. *Solar Energy*, vol. 214, pp. 239–247, Jan. 2021, doi: 10.1016/j.solener.2020.11.029

Thermal losses – and the mythical U-value

«Air cooled»
Mounted above the water

«Water cooled»
Thermal contact with water

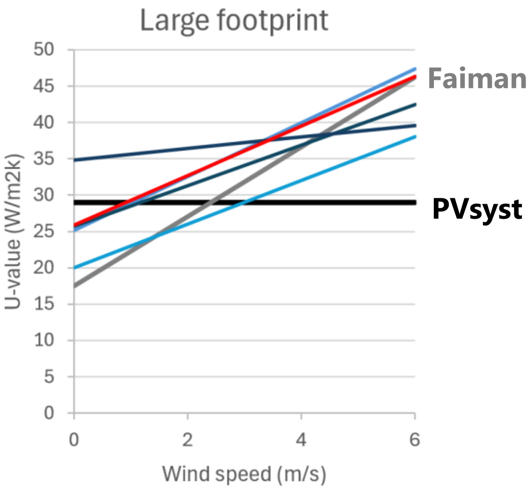
Example technologies

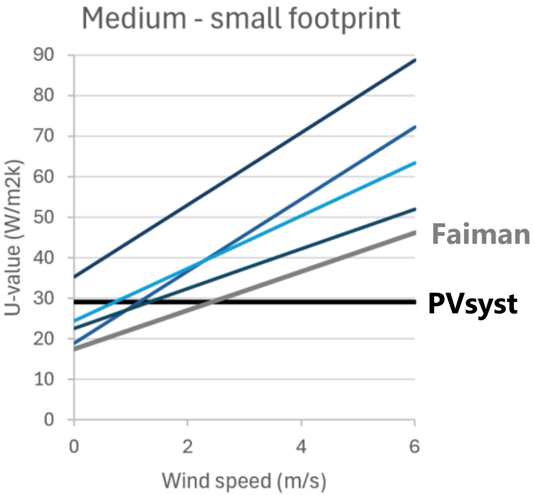


Increasing U-value = ability to exchange heat

71 W/m²K

Reported U-values





M. Dörenkämper et al. *Solar Energy* 2021
V. Nysted et al. *EPJ PV* 2024
M. Dörenkämper et al. *Energies* 2023
T. Kjeldstad et al. Solar *Energy* 2021,
D. Faiman, *Prog. Photovolt: Res. Appl*. 2008

Thermal losses – modelling

PVSyst

$$T_c = T_a + \frac{POA \cdot \alpha \cdot (1 - \eta)}{U_c + U_v \cdot ws}$$

Uc and Uv can be set
Default value set to Uc = 20 W/m²K
Open rack systems Uv = 29 W/m²K
Uv = 0

PVlib

pvlib – community-developed open-source toolbox

pvlib supports several models including Faiman and Pvsyst

Appropriate heat loss coefficients should be used

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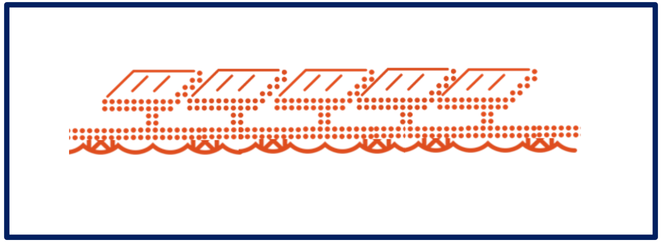
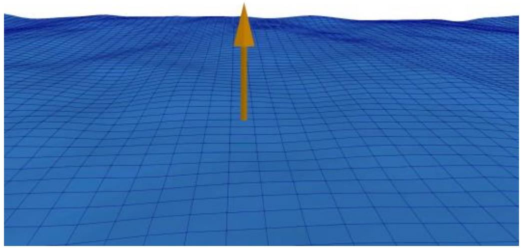
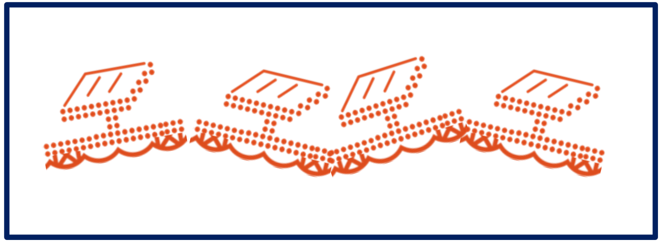
Wave induced losses – varying irradiance

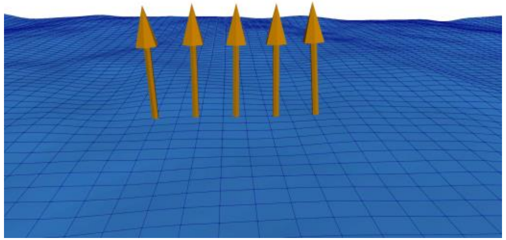


Changes in effective tilt – loss or gain





Orientation **mismatch**



Level of wave induced losses highly system dependent

Number of modules per floater
Floater interaction with waves

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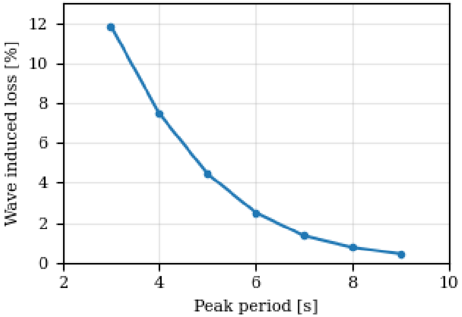
Wave induced mismatch losses

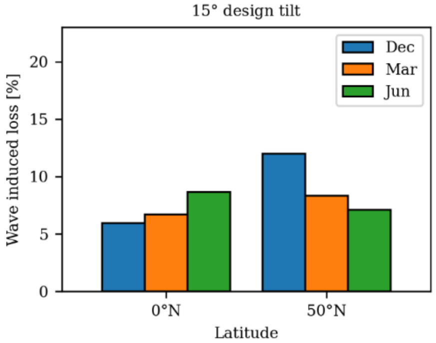
Computed **example** values

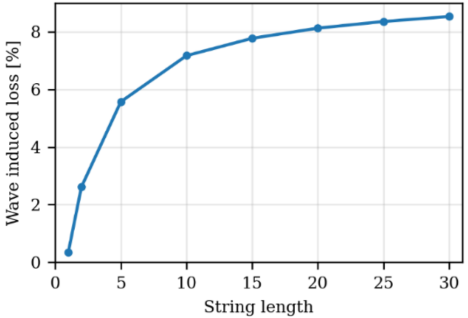
Parameters affecting the losses

- Floater wave interactions
- Sea state (height and wave steepness)
- Solar angle (latitude, time of year, module tilt)
- String length

FPV on lakes, dams and reservoar WIL is small or moderate
WIL more pronounced at non-optimal design tilt
WIML saturates with increasing string length







V. Nysted et al. *Under review*

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Waveinduced losses – modelling

PVSyst

Constant loss factor, valid for whole simulation

Includes mismatch due to dispersion of efficiency (set to 2 %)

Modelling of WIL must be done outside PVSyst

Pvlib

Allows for full modelling of WIL:

Module orientation from external wave module

Pvlib can simluate incident irradiance for each module and passed into pvlibs electrical functions

- PVmismatch – into pvlib

Soiling losses

Likely less soiling from particles

Water available for cleaning

Bird droppings could be a severe challenge

Cleaning could be challenging

Area of high interest

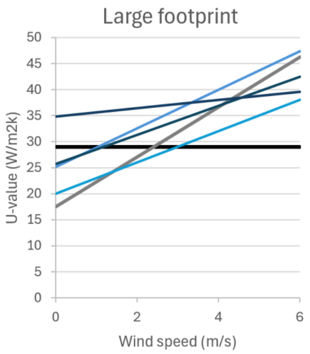
But with a very large knowledge gap!

SERIS’s FPV testbed at Tengeh Reservoir, Singapore

Making engineering considerations more precise

Thermal losses

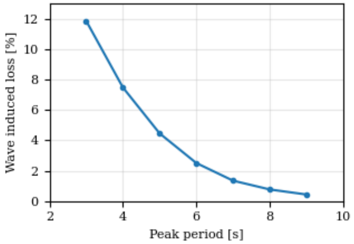
Air flow beneath modules
Wind conditions at site



Wave induced losses

Number of modules per floater
Floater interaction with waves

Height and steepness of waves
Latitude and POA vs optimal angel



Soiling losses

Usually between 1-3%, depending on site and conditions and cleaning

NOTE: VERY little has been published on soiling levels for FPV

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