PV String Partial Shading Loss with and without Bypass Diodes

Power of a PV string with some cell groups shaded, with bypass diodes skipping the shaded substrings, against a string limited by the shaded cell's current.

Method: Series-string shading with bypass diodes

Input parameters

Unit system: SI

Parameter	Value	Unit
Modules in the string	20.000	
Bypass diodes (substrings) per module	3.0000	
Substrings containing a shaded cell	1.0000	
Shaded fraction of the worst cell	50.000	%
Module maximum-power voltage	41.500	V
Module maximum-power current	9.6000	A
Bypass diode forward voltage	0.40000	V

Calculated results

Parameter	Value	Unit
Unshaded string power	7.9680	kW
Power with bypassed substrings	7.8314	kW
Loss with bypass diodes	1.7149	%
Power if the string current follows the shaded cell	3.9840	kW
Loss without bypass	50.000	%

Notes for this case

• Simplified series model: each bypassed substring drops its share of voltage plus a diode drop while current stays at I_mp; without bypass the whole string current falls to the shaded cell's (1 − s)I_mp. Inverter MPP tracking picks the better of the two; real I-V curves have several peaks.

Formula and method

$$P_{bypass} = I_{mp}\left[NV_{mp} - k\left(\frac{V_{mp}}{n_d} + V_d\right)\right], \quad P_{limited} = (1-s)NV_{mp}I_{mp}$$

Variables

N	Modules in the string	-
n_d	Bypass diodes (substrings) per module	-
k	Substrings containing a shaded cell	-
s	Shaded fraction of the worst cell	-
V_{mp}	Module maximum-power voltage	V
I_{mp}	Module maximum-power current	A
V_d	Bypass diode forward voltage	V
P_0	Unshaded string power	W
P_{bypass}	Power with bypassed substrings	W
$1 - P_b/P_0$	Loss with bypass diodes	-

$P_{limited}$	Power if the string current follows the shaded cell	W
$1 - P_n / P_0$	Loss without bypass	-

Method and standards

String shading estimate.

Assumptions and limits

- Identical modules; simplified I-V behaviour.

References

Series-string shading with bypass diodes

Report details

Report reference	FCC-3595-TKTD (the same inputs always give the same reference)
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Calculator	PV String Partial Shading Loss with and without Bypass Diodes
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Software release	FireCAD Calc, release of 22 November 2026
Release checks	3 reference cases of this calculator, computed independently, are checked on every release

Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.

This calculator online

https://calc.firecad.com/electrical/solar-pv/pv-partial-shading-bypass-loss

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.