Safeguarding Solar PV Revenues

Addressing the Challenge of String Inverter Failures in Solar PV Systems

Why inverters fail and how to protect your projects

Insights from

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PVEL
MAKE DATA MATTER.

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kiwa

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Executive Summary

Risk Profile

1. **Frequency & Impact:** 70% of failure events are related to inverter failures which can reduce yield significantly. 50% of inverters cost up to three times more than estimated.
2. **Root cause:** poor workmanship, firmware challenges, quick uptake of high kVA inverters without reliability testing.
3. **Concern:** inverter failures are a key concern for solar assets; impacting NPV, increasing OPEX costs up to 23% and reducing the potential for re-financing due to underperforming parks.

Mitigation Measures

- Product Qualification Program
- Inverter Batch Testing & Technical Advisory
- O&M & Monitoring Platform Selection

Up to 107 EUR/kWp/year
Cost of inverter failures

Up to 90 EUR/kWp/year
Costs Savings

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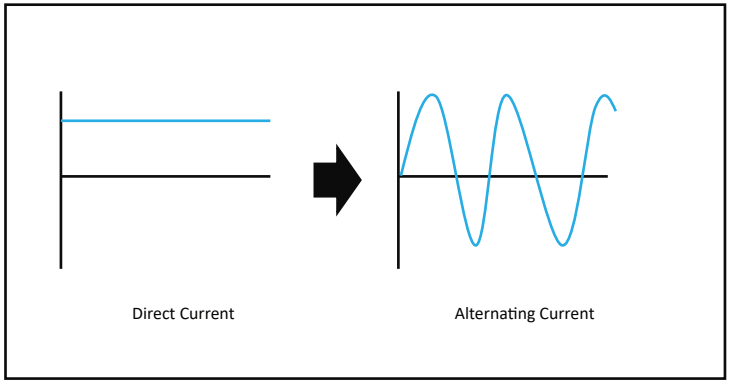
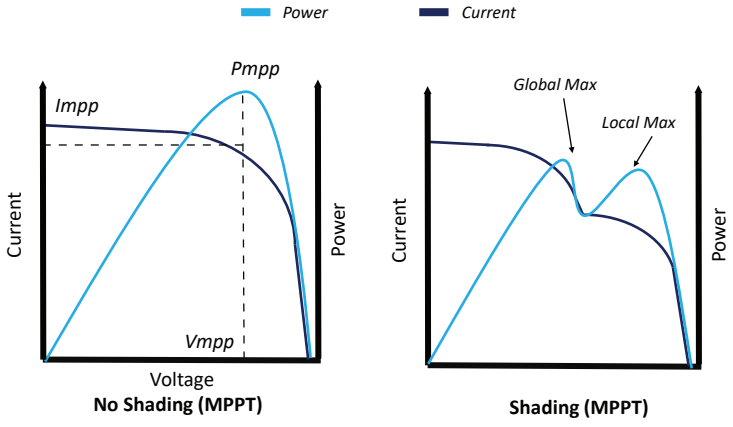
String Inverters Explained

What do string inverters do?





String Inverters convert direct current (DC) to alternating current (AC) interfacing into the gird the AC power at its maximal power output. In parallel it ensures safe PV system operation aggregate data (Impp, Pmpp, Vmpp, Operating Status, kWp, kVA) for monitoring by stakeholder.

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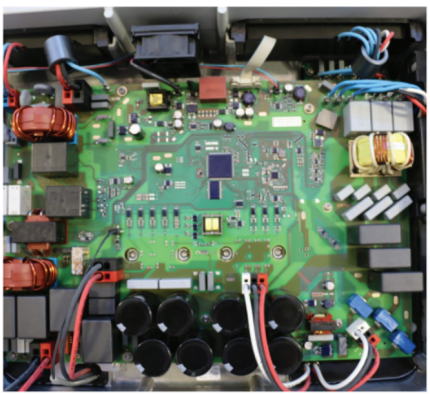
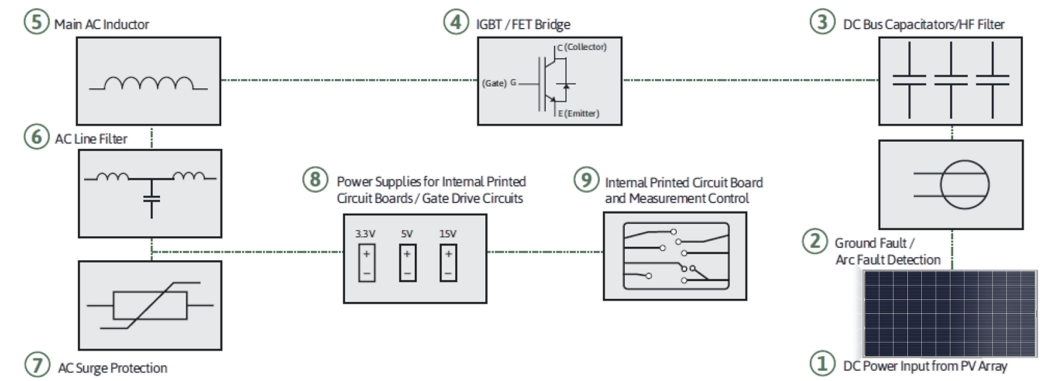
String Inverters Explained Part 2

How do String Inverters convert DC into AC?





Inverters have to be multi-functional and thus contain hundreds of unique, sensitive internal components. Moreover, the operating software is complex in order to handle its various functions.

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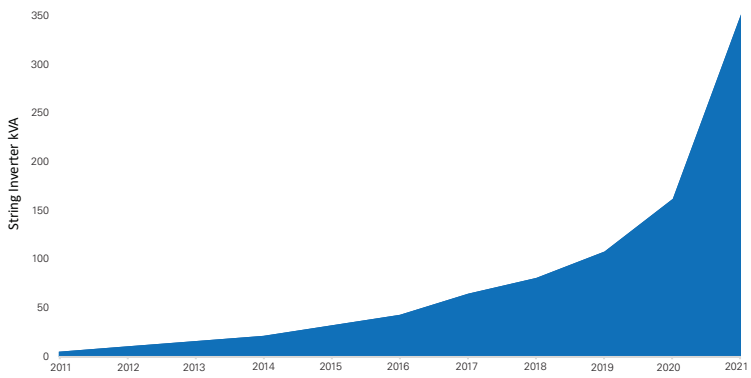
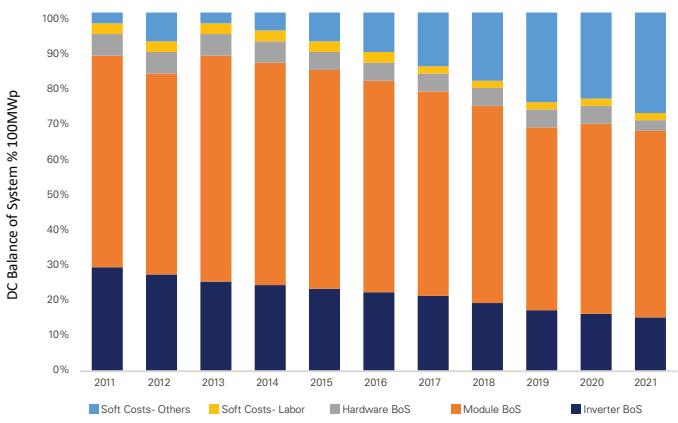
Bright Solar Future - More kWp per inverter & dropping costs



Inverter roadmap- more kWp per inverter

Inverter Costs:
2014 0.10 EUR/Wattpeak (Wp) forecast 2050 0.021 – 0.0035 EUR/Wp



Overall drop in balance of system costs & percentages

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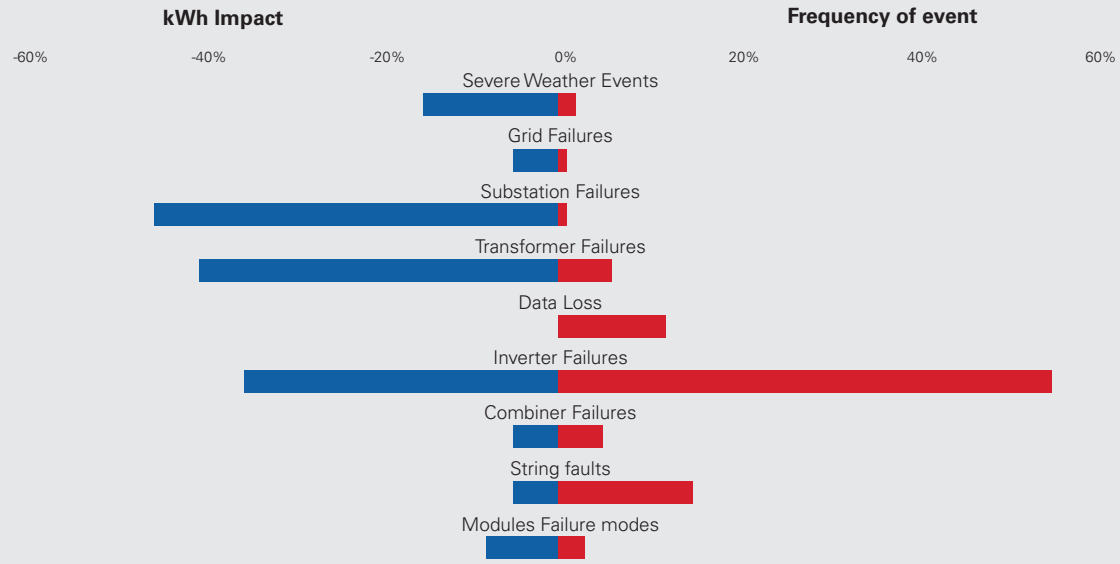
String inverters the weakest link in the chain



60% of failure events during the lifetime of a PV project are due to inverters. They can have up to 30% impact on yield production.

*variation depends on age of the system, type of technology, production quality, firmware, level of over-dimensioning, installation quality, location of inverter, handling, maintenance operations, O&M response & fix times, site conditions & climate

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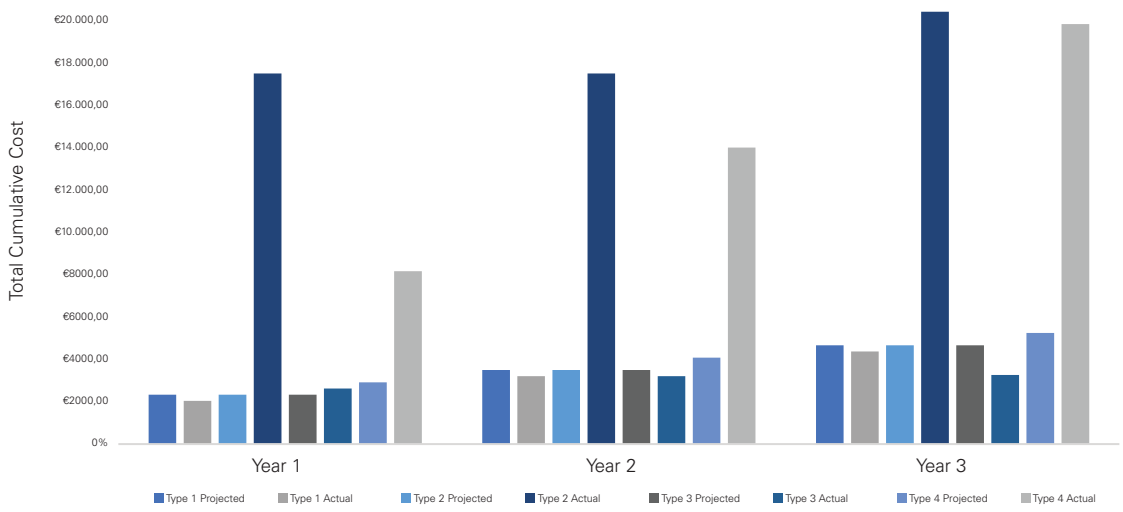
2 out of 4 string inverters cost more than forecast



2 out of 4 string inverters cost three times more than forecasted.

*variation depends on age of the system, type of technology, production quality, firmware, level of over-dimensioning, installation quality, location of inverter, handling, maintenance operations, O&M response & fix times, site conditions & climate

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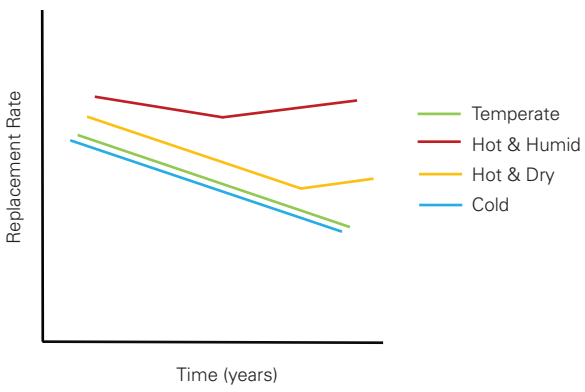
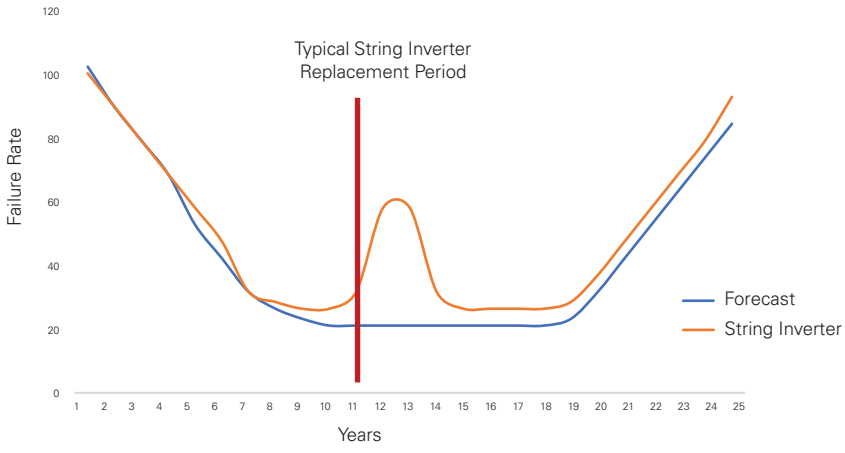
Typical failure rates over the lifetime and per climate





Replacement Rate of Inverters*

Bath Tub Risk Model**

*note that O&M does not cover the cost of structural replacement of inverters in their contracts- often billed separately and hourly. Depends on model type, maintenance and overdimensioning.

** Failure rates typically rise signficantly with introduction of new model types and/orfirmware.

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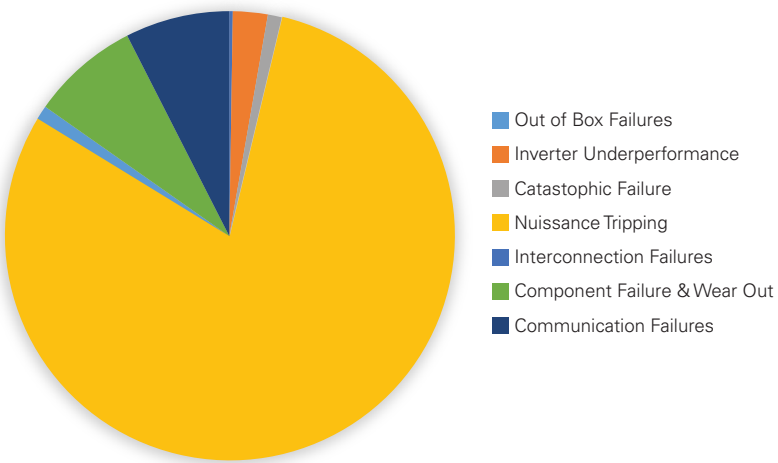
Inverter Failure Root Causes and Costs



Most Inverter Failures

	Cost EUR/kWp/year
Fan Failure & Overheating	1.5
Wrong Installation	1.4
Burned Supply Cable and/or Socket	0.6
Inverter not operating	0.5
Fault Due to Ground	0.2
DC Fuse Failure	0.2
Swith Failure	0.2
Polluted Air Filter	0.2
Wrong Connection	0.1

Example Inverter Failures & their costs

*a large proportion of failures are due to poor workmanship and design of the DC side of the park and/or poor maintenance and monitoring

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Case Study

"PVEL Inverter Reliability testing indicates that inverters often do not meet datasheet requirements either due to environmental conditions, level of maintenance and its operational configuration as most tests are done in lab and not stress tested"

In the first five years of solar project operation, inverters are among the top determinants of economic success. When an inverter does not perform as expected, it almost always results in underperformance and economic losses."

Joe Song VP of Project Operations, Sol Systems

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As it may result in extensice losses

No mitigation measures means higher OPEX costs, which in turn overestimate LCOE calculations

=

	Cost EUR/kWp/year	Cost Saved EUR/kWp/year
Fan Failure & Overheating	1.5	0.2
Wrong Installation	1.4	0.5
Burned Supply Cable and/or Socket	0.6	0.3
Inverter not operating	0.5	0.25
Fault Due to Ground	0.2	0.25
DC Fuse Failure	0.2	0.1
Swith Failure	0.2	0.1
Polluted Air Filter	0.2	0.1
Wrong Connection	0.1	0.1

+ up to 23% more OPEX costs

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Mitigate these risks by:

- O&M Selection
- Product Qualification Programs
- Advanced Monitoring Platform
- Site Inspections
- Inverter Pre-Shipment Inspections
- Technology Validation

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Added value of mitigating risks

Up to

3.2

EUR/kWp/year

SAVED

Typical loss for a 0,10 EUR/kWh project without mitigation strategies equates to a total loss of 5.4 EUR/kWp/year. Implementing previously stated risk strategies reduces those total losses to 2.2 EUR/kWp/year.

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Find out how Kiwa can be your partner in progress for safeguarding long term solar investments

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Co-written with: PVEL MAKE DATA MATTER.

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