

Executive Summary

Risk Profile

- Frequency & Impact:** 18% of parks show some degree of PID. Increasing in frequency & severity from 5-10% in the last 5 years. Impacting yield significantly by >30% even with "PID free" certified modules.
- Root cause:** quick uptake of new technologies, their material selection, system design and impact of local climate.
- Concern:** module testing shows PID is a key concern for solar assets; impacting IRR from 13.58% to 4.68% & in turn may lead to default on loan repayments.

Mitigation Measures

- ★ PID certified modules and Product Qualification Program
- ★ Bill of Materials Specification & Technical Advisory
- ★ Batch and Site Testing (Infrared & EL imaging) of greenfield & brownfield projects

6 EUR/kWp/year
Cost of PID

3.4 EUR/kWp/year
Costs Savings

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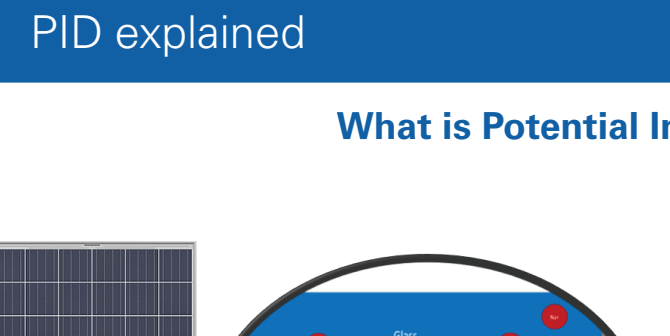
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To profit you must mitigate technical risks- Increased frequency of PID severity

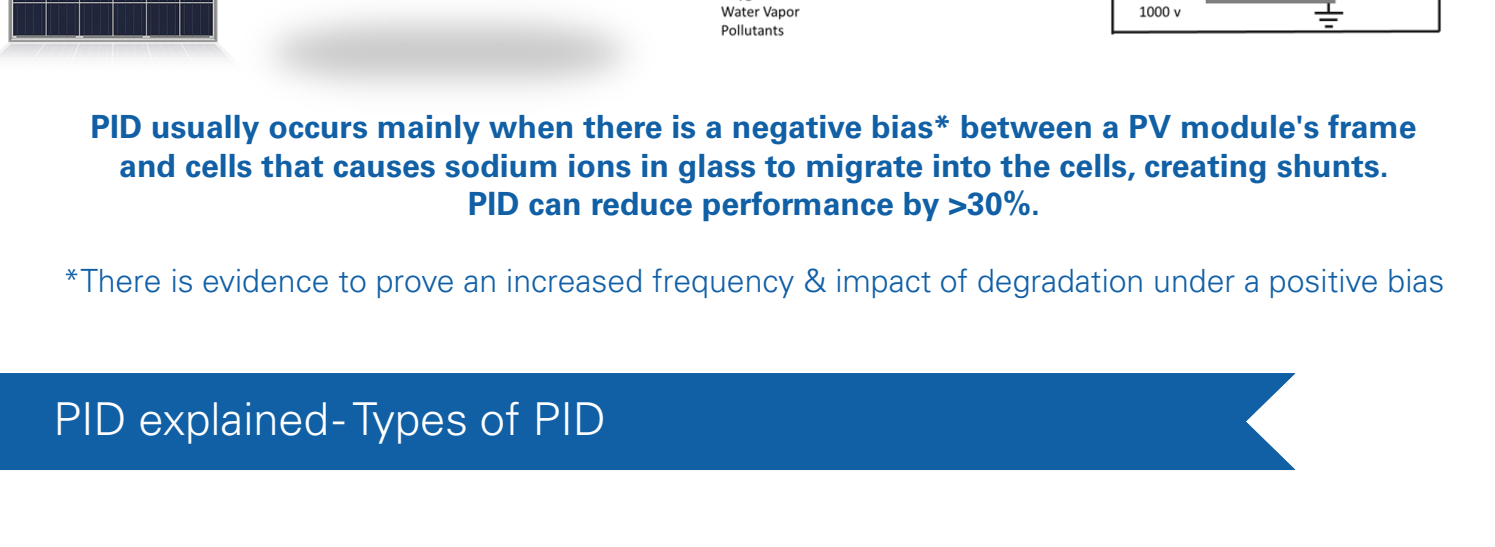


According to studies conducted by NREL; PID is becoming one of the main challenges, doubling in frequency and gaining severity*; as field modules not always representative of IEC62804 PID certified modules

*depending on climate, system design, module technology- surge of new technologies may impact PID frequency

PID explained

What is Potential Induced Degradation (PID)?



PID usually occurs mainly when there is a negative bias* between a PV module's frame and cells that causes sodium ions in glass to migrate into the cells, creating shunts. PID can reduce performance by >30%.

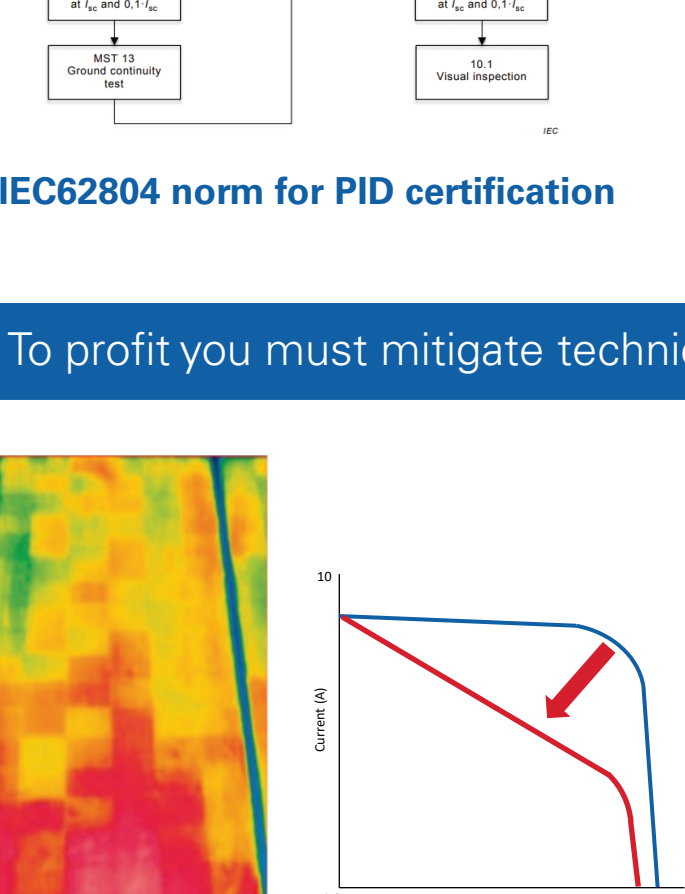
*There is evidence to prove an increased frequency & impact of degradation under a positive bias

PID explained- Types of PID

- PID-s**
Ag finger
SiNx
n-diffused emitter
P-type CZ wafer
- PID-c**
BSF
- PID-p**
AlOx
SiNy
Al finger
- PID shunting (PID-s)**
Combination of conductive non-optimized antireflection coating & sodium (Na+) deposition during lamination or processing or ions migrating from the glass
- PID polarization (PID-p)**
Temporary reduction of rear side passivation
- PID corrosion (PID-c)**
Corrosion of silicon semiconductor material (rare)

Bifacial modules are gaining market share, but PERC+ bifacial PID is concerning

Bright Solar Future - Mitigating PID with norms & test schemes



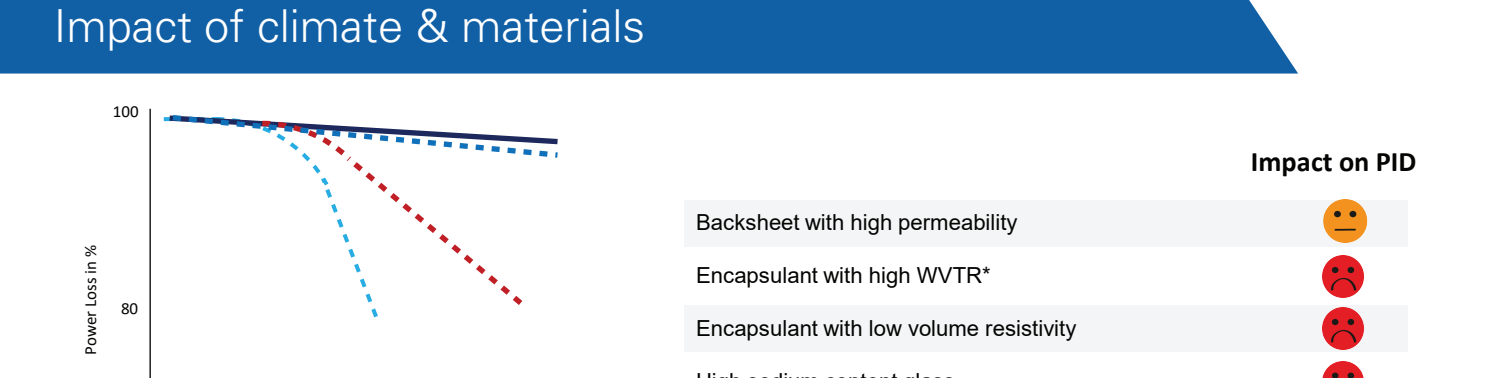
IEC62804 norm for PID certification

Factory Witness, Characterization and Light-Induced Degradation Measurement

Normal Durability	Temp. Peak	Backsheet Durability	Mechanical Stress Resistance	Frontal Plane Irradiance	UVD (UV Light)	UVF (UV Light)	UVH (UV Light)	UVI (UV Light)	UVJ (UV Light)	UVK (UV Light)	UVL (UV Light)	UVM (UV Light)	UVN (UV Light)	UVO (UV Light)	UVF (UV Light)	UVG (UV Light)	UVH (UV Light)	UVI (UV Light)	UVJ (UV Light)	UVK (UV Light)	UVL (UV Light)	UVM (UV Light)	UVN (UV Light)	UVO (UV Light)
UV 100	UV 100	UV 100	UV 100	UV 100	UV 100	UV 100	UV 100	UV 100	UV 100	UV 100	UV 100	UV 100	UV 100	UV 100	UV 100	UV 100	UV 100	UV 100	UV 100	UV 100	UV 100	UV 100	UV 100	UV 100

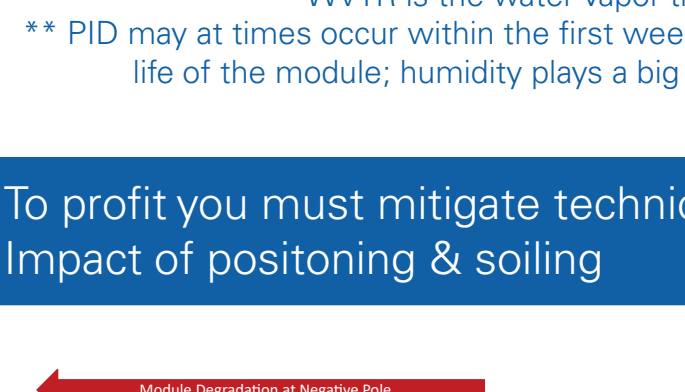
PVEL's Product Qualification Program includes extended PID testing

To profit you must mitigate technical risks- Detecting PID



System Performance Ratio*
*Impact of PID is only detectable at a very late stage of degradation in performance ratio or monitoring platform

To profit you must mitigate technical risks - Impact of climate & materials



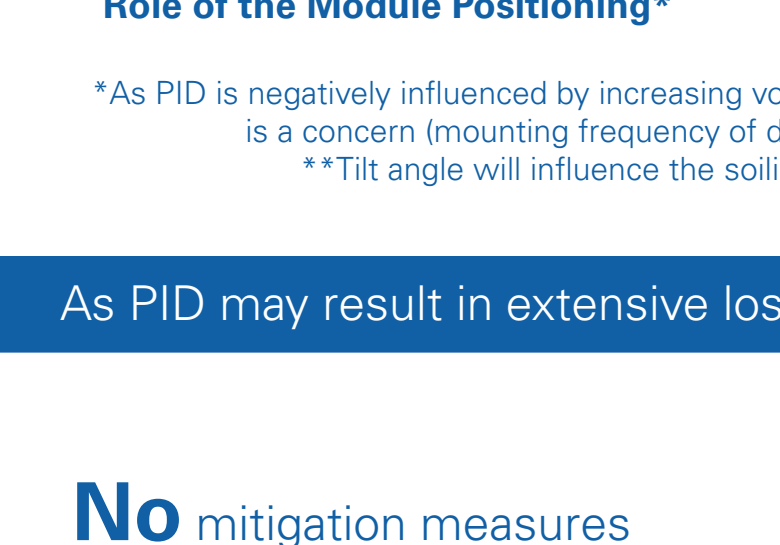
Impact of Climate on PID**

- Impact on PID
- Backsheet with high permeability (Yellow smiley)
 - Encapsulant with high WVTR* (Red smiley)
 - Encapsulant with low volume resistivity (Red sad smiley)
 - High sodium content glass (Red sad smiley)
 - Photovoltaic cell with non-optimized anti reflection coating (Red sad smiley)

Role of Bill of Materials in PID
Surge of new technologies increases concern for PID risk

**WVTR is the water vapor transmission rate of a material
** PID may at times occur within the first weeks/months, but typically occurring during the mid life of the module; humidity plays a big role (light intensity weakens the impact)

To profit you must mitigate technical risks - Impact of positioning & soiling



Role of the Module Positioning*

*As PID is negatively influenced by increasing voltage; higher system voltages (1000->1500V) is a concern (mounting frequency of degradation under positive bias PID)
**Tilt angle will influence the soiling and therefore impact of PID

Soiling increases PID for sensitive modules**

As PID may result in extensive losses

No mitigation measures means lower CAPEX costs, but higher than anticipated OPEX costs & lower yields

Up to **6*** EUR/kW p/year **LOSS**

Cost of mitigation measures to mitigate PID will increase CAPEX slightly, but in turn reduce OPEX costs and increase yield

*calculated by Solar Bankability to be the economic losses from PID in terms of downtime, costs to repair or fix with relation to operational costs (OPEX)

Case Study

"Above has detected suspected PID in 18% of the plants that we have inspected to date; even plants at commissioning in Spain and the UK with 'PID free modules' too."

Many module datasheets continue to advertise products as "PID resistant," yet both the median and average degradation from PID was higher in the 2021 PV Module Reliability Scorecard dataset than in the 2020 Scorecard dataset—the highest in PVEL's history.

Mitigate these risks by:

- ★ IEC62804 PID certificate
- ★ IEC62446 Thermal and/or EL site testing
- ★ Batch and Site Testing
- ★ BOM Specification & Supply Chain Management
- ★ Product Qualification Programs
- ★ Technology & Design Review-Technical Advisory
- ★ Asset Audits/Health Checks
- ★ O&M & Monitoring Selection

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.

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

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