PCREEE Pacific Centre for Renewable Energy and Energy Efficiency
SE4ALL Centre of Excellence to Promote Sustainable Energy Markets, Industries and Innovation

ISA International Solar Alliance

INES Institut National de l'Energie Solaire

Specificity of solar micro grids in island areas

Government of Tonga / PCREEE / ISA / INES PFE

SESSION 6
Maintenance

Micro-grid in Corsica named « Myrte »

Specificity of solar micro grids in island areas

SESSION 6: Don't overlook the importance of maintenance !

(Olivier VERDEIL)

- Maintenance objectives
- Preventive maintenance
- Corrective maintenance
- Common defects in solar microgrid
- Focus on PV modules, inverters and batteries pathologies
- Maintenance in the light of natural disasters
- Case-study : Tuvalu storage system

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Maintenance objectives

- ✓ Ensure **service continuity** (limit production cuts and economic losses)
- ✓ Ensure **safe operation** (for material and people)
- ✓ Carry out **actions to optimize operation**, to the expected level
- ✓ **Anticipate material failures** (information system, maintenance policy, indicators, etc.)
- ✓ **Manage major maintenance** and renewal on a fixed date
- ✓ **Establish procedures and methods** for carrying out maintenance
- ✓ **Carry out interventions** (preventive, corrective)
- ✓ Manage spare parts

Maintenance actors

- ✓ **Operator**
- ✓ **Specialized maintenance technician**
- ✓ Equipment manufacturers

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Preventive maintenance (observations and recommendations should be documented in a written report)

<u>VISUAL INSPECTIONS</u> (80% of maintenance work):

⇒ **Checking the general good appearance of the supporting structure** (no displaced or deformed parts, no traces of corrosion, ...)

⇒ **Checking the general appearance of the PV modules**
(well fixed and connected, frame in good condition, state of cleanliness, glass not broken, cells not showing pathologies, good condition junction box / cables / connectors / busbar, ...)

⇒ **Check of the good general appearance of the inverters / regulators / monitoring**
(well fixed and connected, LED and display not indicating abnormal status, nothing prevents the good ventilation of these devices, ...)

⇒ **Check of the good general appearance of the batteries**
(well fixed and connected, good appearance of the hermetic retention tank, casing of each battery not cracked, good electrolyte level, no presence of corrosion and sulphation, good ventilation of the batteries room, ...)

⇒ **Control of the good general appearance of the AC & DC electrical boxes, cable tray**
(well fixed and connected, no trace of heating, no presence of foreign object, ...)

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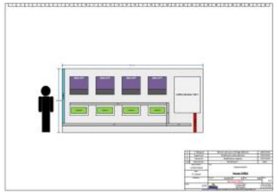
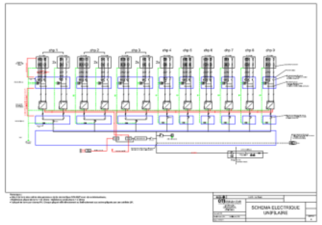
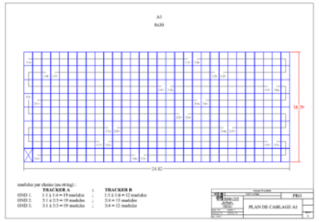
Preventive maintenance (observations and recommendations should be documented in a written report)

VISUAL INSPECTIONS (80% of maintenance work):

=> **Checking the presence of all regulatory signage labels** (on cable trays, cables, AC & DC boxes, electrical devices, etc.)

⇒ **Checking the presence of all technical documentation** (topographic plan, layout diagram, single-line diagram, wiring plan for PV chains, technical data sheets for the various electrical devices, etc.)


⇒ **Spare parts inventory available on site** (inverters, Modules, Cables, connectors, fuses, surge arresters, diodes, ...)

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Preventive maintenance (observations and recommendations should be documented in a written report)

STABILITY & FUNCTIONAL CHECKS:

⇒ **Checks of physical stability and resistance to pullout force** (of the supporting structure, modules, electrical equipment, electrical boxes, cables, …)

⇒ **Checks of the correct mechanical operation of electrical protection devices** (emergency stop, circuit breaker, disconnector switches, fuse holder, surge arrester,…)

MEASUREMENTS CHECKS:

⇒ **Earth resistance measurement (less than 100 Ohm)**

⇒ **Measurements open circuit voltages of each PV strings,**

⇒ **Measurements operating current of each PV strings**

⇒ **Measurements open circuit voltages voltage of the battery park**

⇒ **Measurements open circuit voltages of each battery**

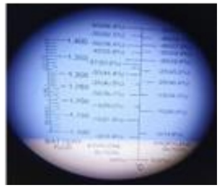
⇒ **Measurements charge and discharge current of the battery park**

⇒ **Measurements acid density of each battery** (if liquid electrolyte)

⇒ **Measurement with a thermal camera of the temperature of all sensitive electrical areas** (PV modules, junction box, connectors, cables, AC & DC boxes, safety devices, etc.)





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Preventive maintenance (observations and recommendations should be documented in a written report)

PV MAINTENANCE SPECIFIC MEASURING INSTRUMENT:

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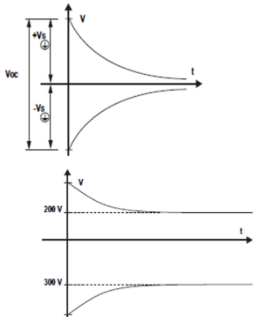

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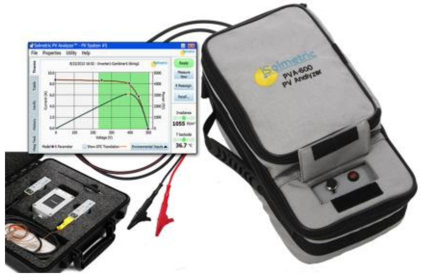

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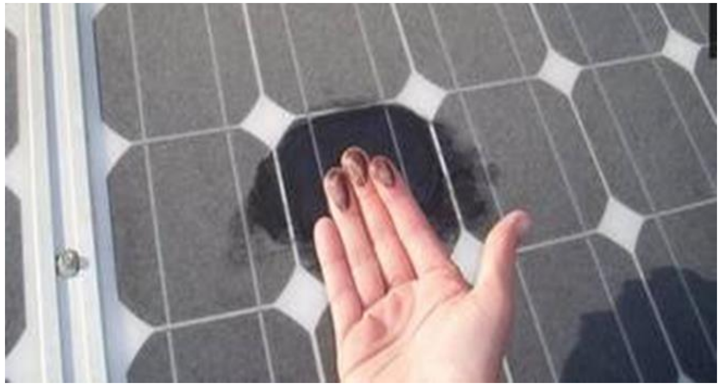
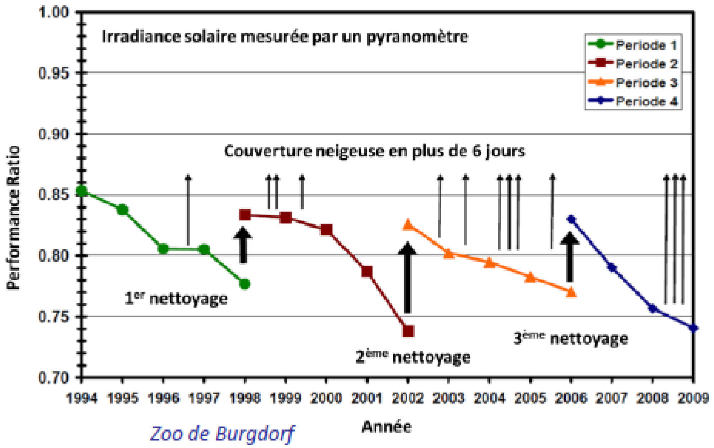
Preventive maintenance (observations and recommendations should be documented in a written report)

PV MAINTENANCE SPECIFIC CLEANING INSTRUMENT:





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Corrective maintenance

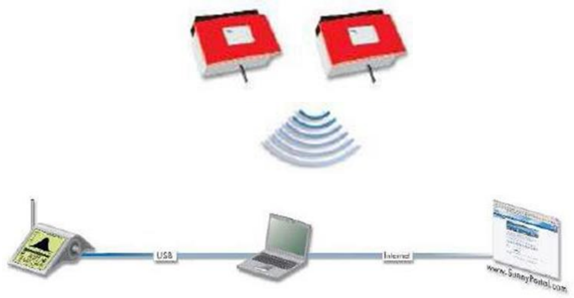
IDENTIFICATION AND RESOLUTION OF A PROBLEM (methodology)

⇒ **Without monitoring system**

- **Advantages:** "traditional" maintenance methods
- **Disadvantages:** no measurement instrumentation, no measurement history allowing a diagnosis, risk of significant on-site intervention time

⇒ **=> Without monitoring system**

- **Advantages:** Alarm raising according to system, speed of problem detection if external probes (irradiation + module temperature) and possibility of establishing a first diagnosis
- **Disadvantages:** it is often complex to interpret the data if you want to diagnose the fault



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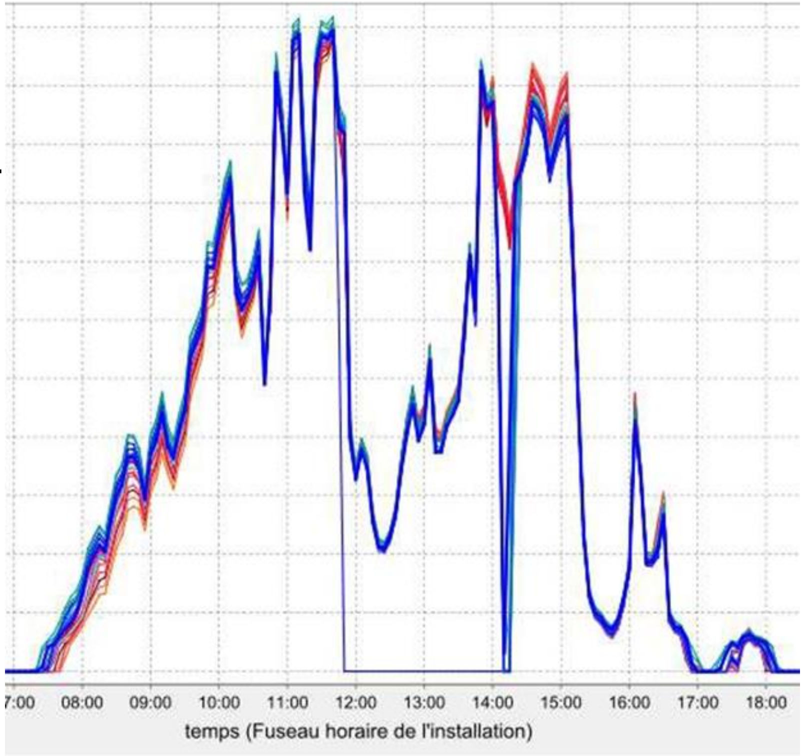
Corrective maintenance



IDENTIFICATION AND RESOLUTION OF A PROBLEM (methodology)

Operations to be carried out:

⇒ Information gathering
⇒ Monitoring Failure search
⇒ Inverter - meter
⇒ Indicator (visualization, noise, odor)
⇒ External service providers (roofer, electrician)
⇒ Analyse
⇒ History - Weather occurrences,
⇒ special conditions Comparisons
⇒ Identification of fault zone AC or DC
⇒ Failure resolution

⇒ **If resolution is not possible immediately: secure the installation** (disconnection of the affected areas with an electrical lockout padlock)

Intervention frequency: As soon as necessary!

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Common defects in solar microgrid (somes examples)

- ⇒ PV modules never cleaned
- ⇒ Presence of shading on the PV array
- ⇒ Installation team not sufficiently trained in the various safety recommendations
- ⇒ Poor quality of equipment
- ⇒ Wrong sizing of cable sessions
- ⇒ Matching connectors that are not identical
- ⇒ Poor crimping quality of PV connectors (with multigrip pliers)
- ⇒ Overvaluation of solar production
- ⇒ Underestimation of customer consumption
- ⇒ Lack of campaign to tighten electrical terminal blocks
- ⇒ Premature aging of equipment
- ⇒ Electric arc formation, see fire start
- ⇒ Poor ventilation of the battery room
- ⇒ Lack of monitoring and maintenance of the installation

!!! Very large induction loop!!!

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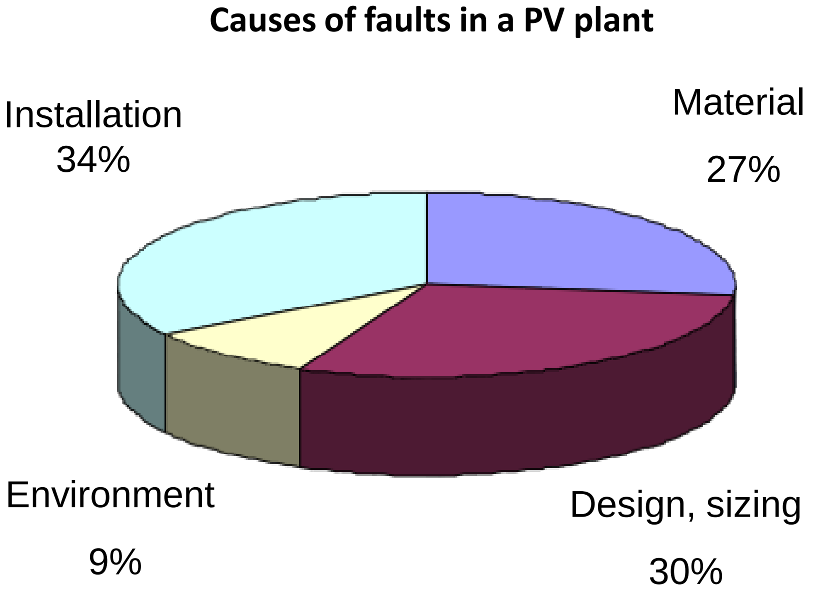
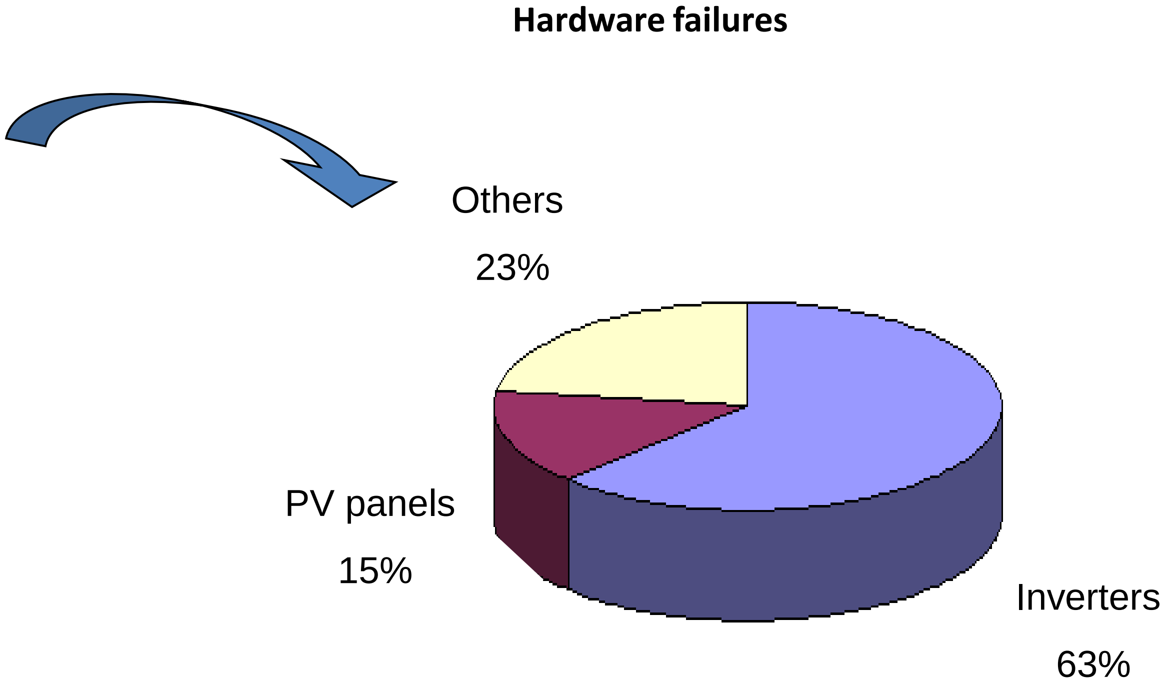
Common defects in solar microgrid

DEFECT STATISTICS:





➔ « Human causes » : 34 + 30 = 64 % !

(Study carried out on 21 different On Grid Systems, over 10 years)

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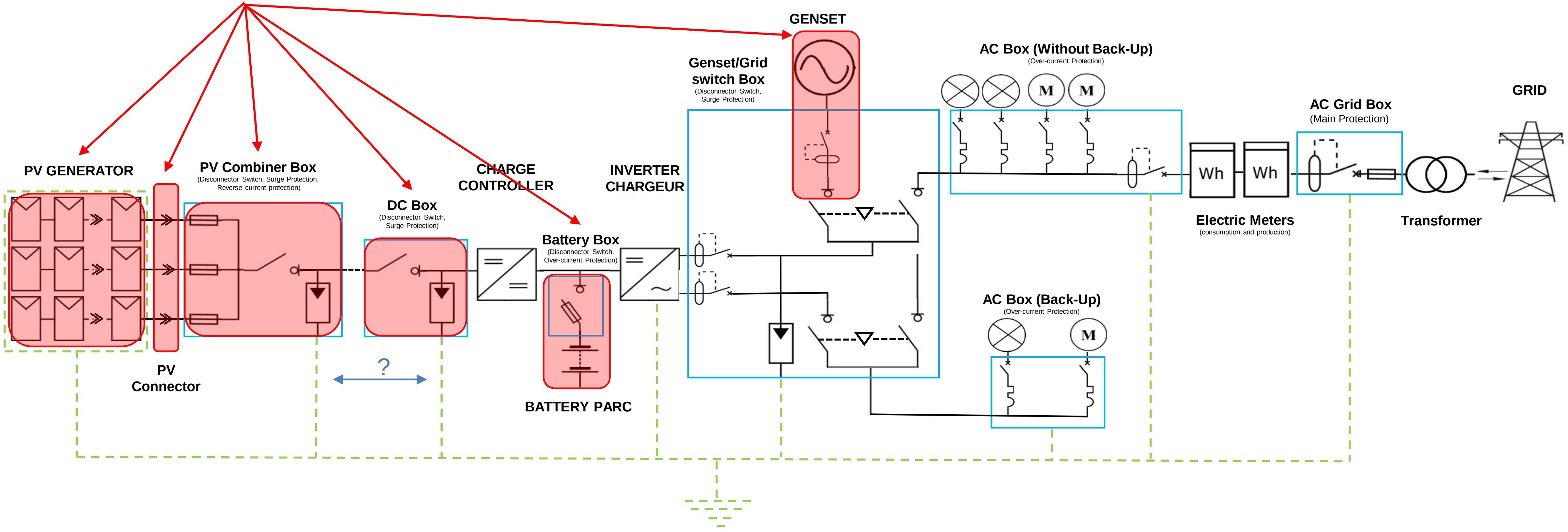
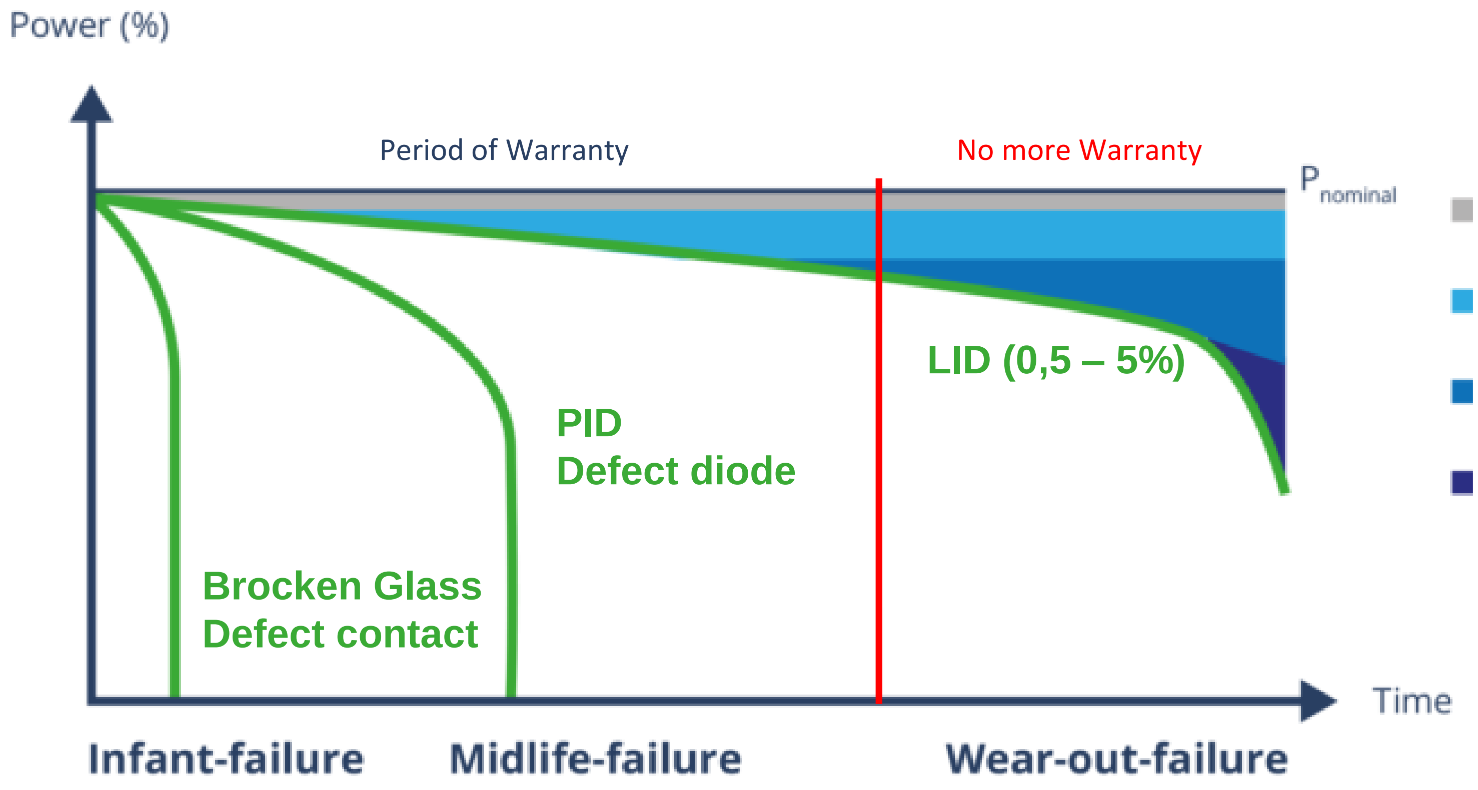
Common defects in solar microgrid

LOCATION OF SENSITIVE POINTS OF A PV INSTALLATION:

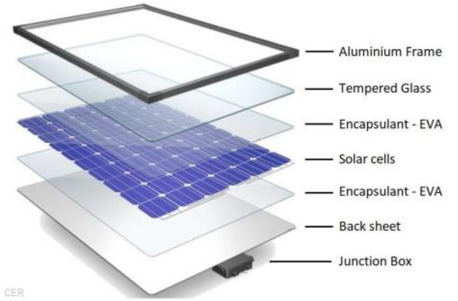


Specificity of solar micro grids in island areas

Focus on PV modules pathologies



- Degradation of AR coating on glass(< 3%)
- Discoloration of encapsulant (EVA) (< 10%)
- Delamination, cracked cell isolation
- Corrosion of cell & interconnection



Specificity of solar micro grids in island areas

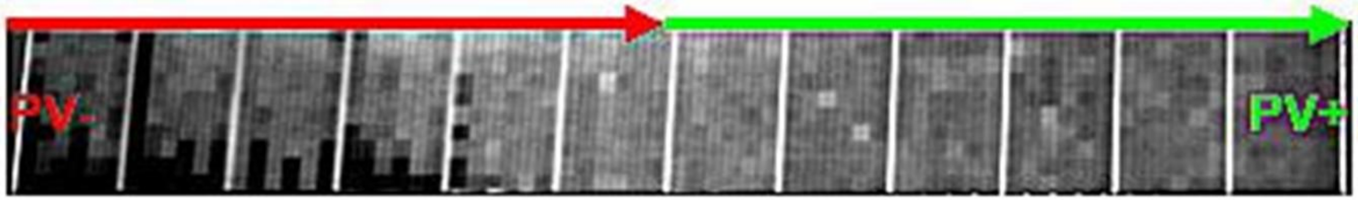
Focus on PV modules pathologies

LID – Light Induced Degradation

This **degradation of cells by sunlight** is highly **dependent on the quality of the wafer** manufactured (specily with Boron doped P substrate cells). Modules experience **power loss** rates of **approximately 3% within the first year** of usage. **Thereafter**, a phenomenon known as "**power stabilization"** is said to occur, which refers to lower levels of power loss in subsequent years of usage at rates **typically around 0.8%.**

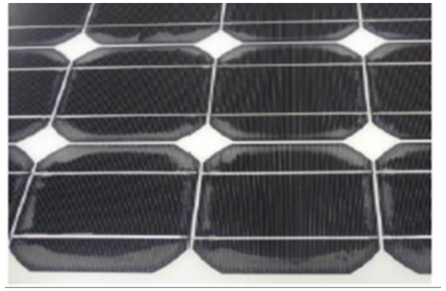
PID – Potential Induced Degradation

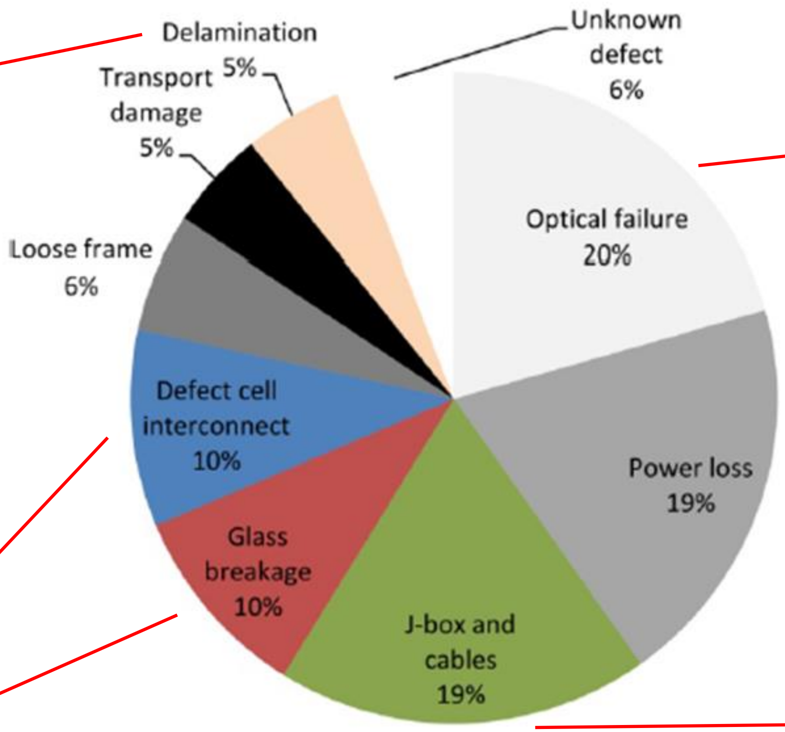
This second form of **degradation caused by high voltages** (>1000 V) and above together with **high temperatures** and **humidity**. Furthermore, the accumulation of dirt and the degradation of glass can **catalyse the process** owing to the **release of sodium ions**. Modules that have experienced such degradation generally contain some black cells that are non-functional and found near the frame. This occurs due to a large flow of electrons through such cells, due to the differential in voltage across the pane.



Specificity of solar micro grids in island areas

Focus on PV modules pathologies





The statistic (A. Richter) is based on a total volume of around **2 million PV modules** delivered between **2006-2010** in German.

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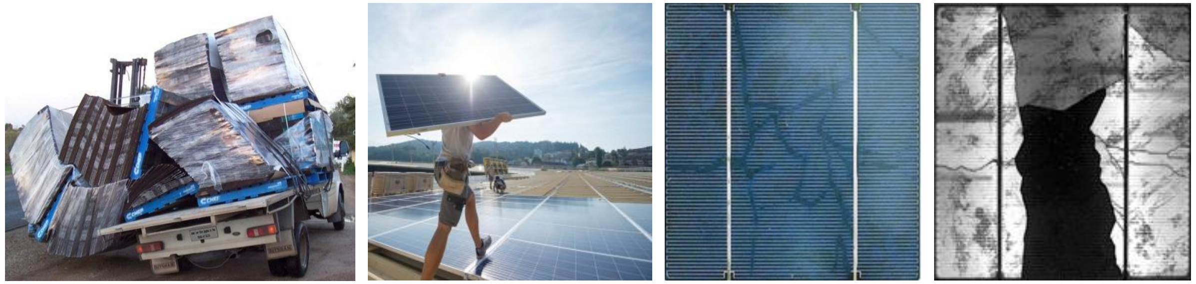
Focus on PV modules pathologies

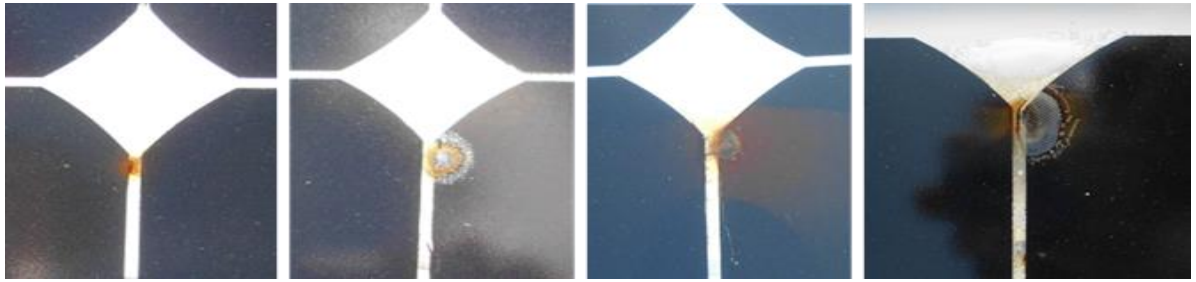
Appearance of " **SNAIL TRAILS** "

(big jerks during transport or installer who stepped on it)



Appearance of **HOT SPOT**

(Hot spot on cell propagating over time)

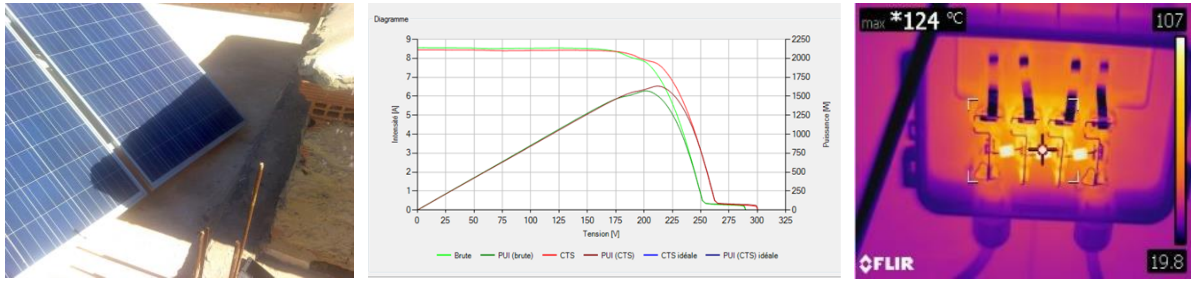


CRUMBLING & **DELAMINATION** & **SLIT** ON BACKSHEET

(Poor UV resistance and poor quality of the encapsulant)

Impact of **SHADING**

Voltage loss / I(V) curve and rise in temperature of the bypass diodes



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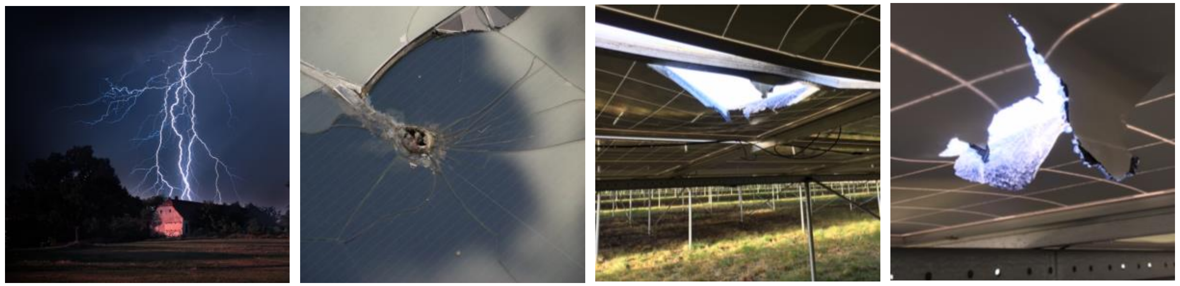
Focus on PV modules pathologies

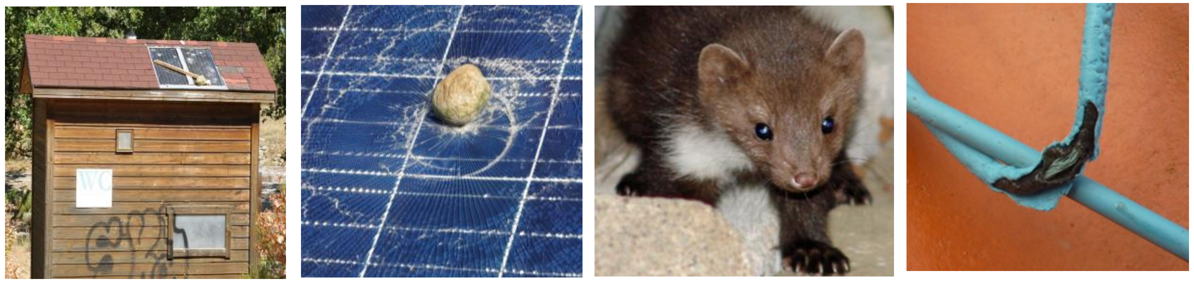
LIGHTNING STRIKE

(Normally modules resist lightning better than invertes)



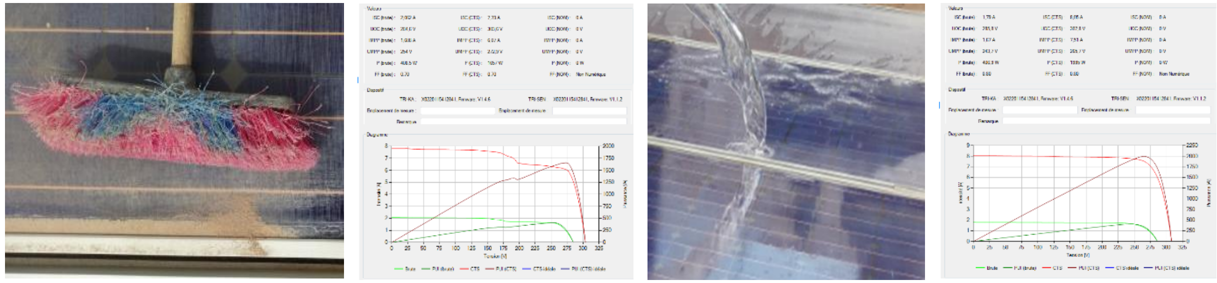
VANDALISM & PREDATOR

(Human stupidity & animal gluttony)



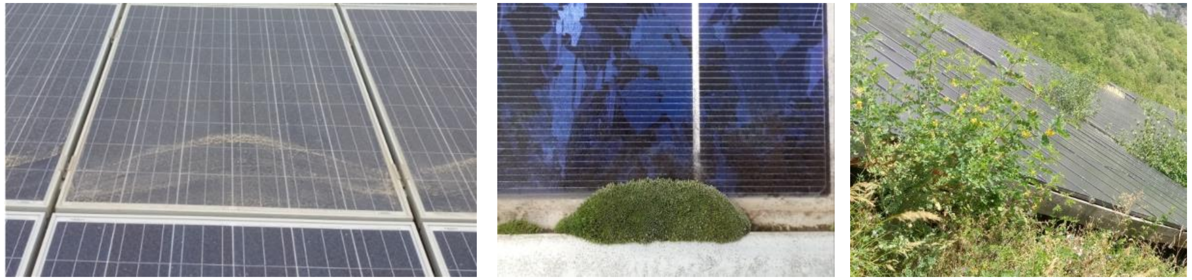
Influence of **SOILING**

(Decrease in current / curve I (V))



UNMAINTENAINED PV MODULE AND FIEDS

(Current and power losses)



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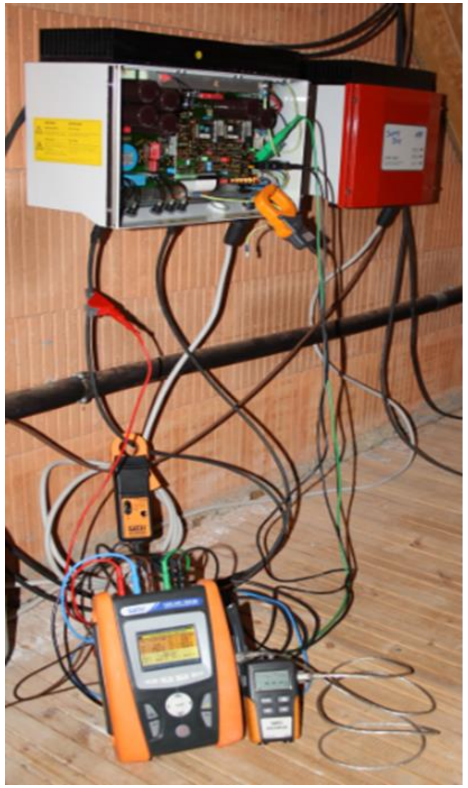
Focus on inverters pathologies

SIGNIFICANT DECREASE IN PERFORMANCE

(premature aging of the DC / AC converter board)



POOR VENTILATION

(Inopportune deposit of objects, lack of cleaning of the ventilation grilles)

UNMAINTENAINED INVERTER

(bird's and wasp's nest, invading vegetation)

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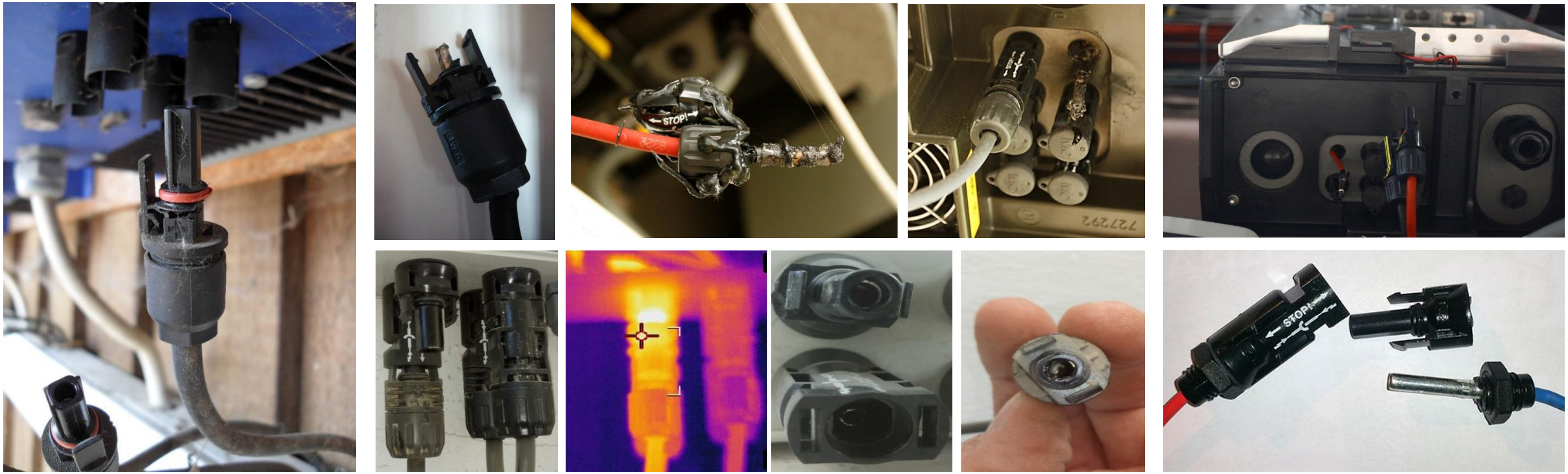
Focus on inverters pathologies

POOR QUALITY OF ELECTRICAL CONTACTS AT INVERTER ENTRY
(Fragility of the connectors embedded in the inverter, poor implementation of the connectors)



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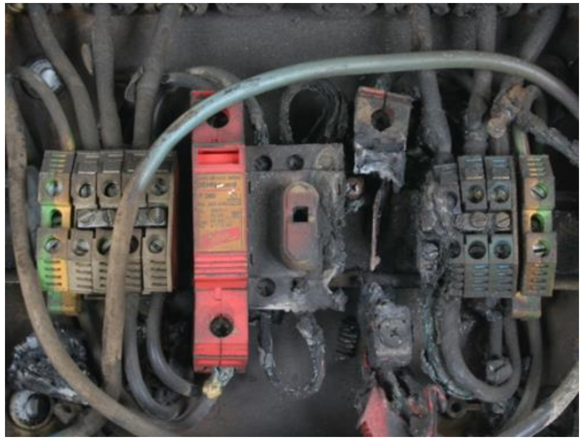
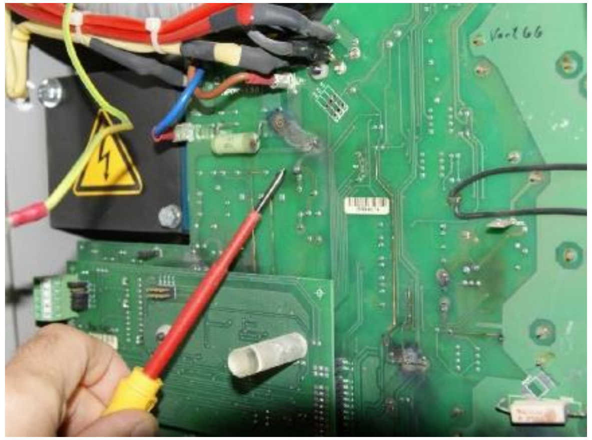
Focus on inverters pathologies

SENSITIVITY OF ELECTRONIC BOARDS TO LIGHTNING

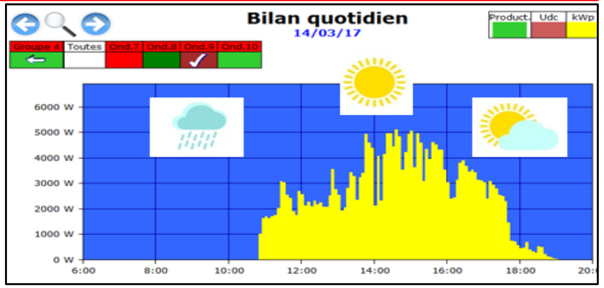
(Despite lightning protection, the inverters remain sensitive to overvoltage)





INSULATION FAILURE = ENDANGERING WORKERS !!!

insulation fault can come from a stripped PV cable, a more waterproof or damaged connectors, ...

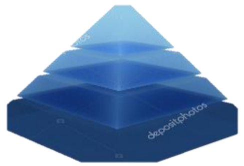


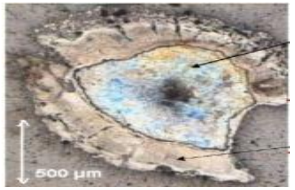
9	14/03/17 10:51:45 - 10:57:36	3 - MPP	115 - isolation error PV_GND
9	14/03/17 07:09:00 - 10:51:44	5 - Fault	115 - isolation error PV_GND
9	14/03/17 07:08:30 - 07:08:59	4 - Preload	-
9	13/03/17 18:54:00 - 14/03/17 07:08:29	255 - Offline	-
9	13/03/17 18:45:30 - 18:53:59	4 - Preload	-
9	13/03/17 18:45:15 - 18:45:29	3 - MPP	-
9	13/03/17 18:45:00 - 18:45:14	4 - Preload	-
9	13/03/17 12:56:00 - 18:44:59	3 - MPP	-
9	13/03/17 12:51:30 - 12:55:59	3 - MPP	115 - isolation error PV_GND
9	13/03/17 12:51:00 - 12:51:29	4 - Preload	115 - isolation error PV_GND
9	13/03/17 12:50:45 - 12:50:59	3 - MPP	115 - isolation error PV_GND
9	13/03/17 12:50:00 - 12:50:44	5 - Fault	115 - isolation error PV_GND
9	13/03/17 12:49:45 - 12:49:59	4 - Preload	115 - isolation error PV_GND
9	12/03/17 18:46:30 - 13/03/17 12:49:44	5 - Fault	115 - isolation error PV_GND
9	12/03/17 07:40:45 - 18:46:29	3 - MPP	-
9	12/03/17 07:37:15 - 07:40:44	4 - Preload	-

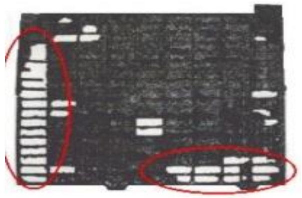
Specificity of solar micro grids in island areas

Focus on batteries pathologies

CAUSE	CONCEQUENCES
➢ Charge without "bubbling" (only for batteries with liquid electrolyte) (equalization program)	• Stratification
➢ Excessive discharge	• "HARD" sulfation
➢ Excessive overload	• Corrosions of negative plates
➢ Cycling at high depths of discharge	• Softening of the positive material and decohesion of the plate







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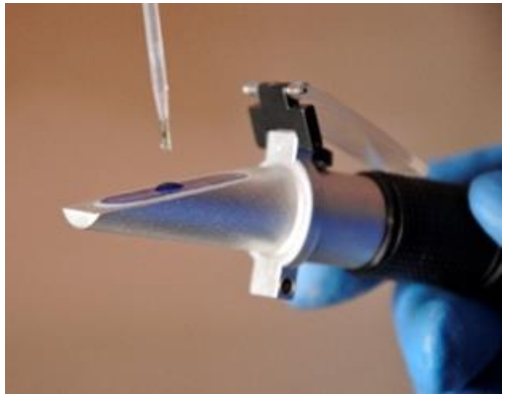
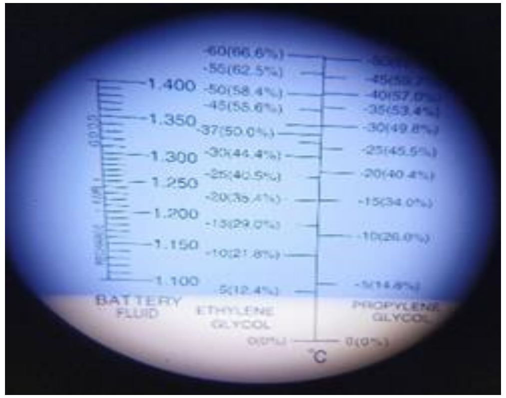
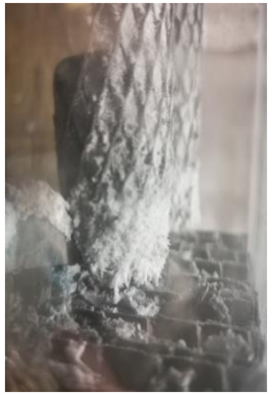
Focus on batteries pathologies





Specificity of solar micro grids in island areas

Maintenance in the light of natural disasters

VOLCANIC ERUPTION CAUSING VERY STRONG SOILING OF PV MODULES

Eruption of the "Cumbre Vieja" volcano (Palma - Canary Islands) – Since September 2021
(Source: PV-Magazine France)

For more than 3 months now, the **eruption of the volcano** has resulted in the **production of a lot of ash**.
Of course, **this ash is regularly deposited on the PV modules** and **clogs the ventilation grids of the inverters**.

Reinforced maintenance is therefore essential !

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Maintenance in the light of natural disasters

THE PASSAGE OF THE HURRICANE CAUSES SIGNIFICANT DAMAGE TO PV PLANTS:

Damage to St Thomas PV plant after Hurricane IRMA
(VIRGIN ISLANDS - Caribbean Sea - US – SEPT 2017)
(Source: “Solar under storm” – Rocky Mountain Institute)

Damage to Illumina PV plant (24MWp) after Hurricane MARIA
(PUERTO RICO in 2018) (Source: Maria Gallucci/IEEE Spectrum)

Such a disaster takes a lot of courage to collect all this destroyed material. This requires having to answer the following questions:

=> **Was this disaster predictable?** If so, have all the **mechanical reinforcement measures** been taken?
=> Will all **this material be able to be recycled**?
=> Are these solar parks covered by **good insurance contracts**?

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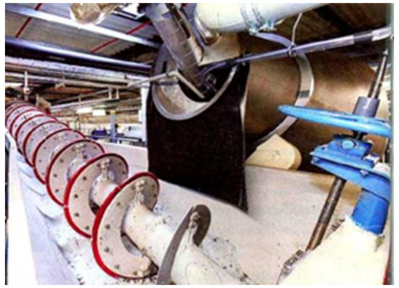
PV MODULE RECYCLING

<u>Today we know how to recycle a PV Modul up to 95% !</u>

- ✓ 95% to 100% of glass is recyclable
- ✓ 100% of electrical conductors are recyclable (copper, silver, aluminum)
- ✓ 100% of the aluminum frame of the PV module is recyclable
- ✓ 75% of PV cells are recyclable (4 life-cycle possible) !!!
- ✓ Plastic materials (EVA, Backsheet, insulation of cables and connectors) will be transformed into granules or will be used to produce energy





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Case-study : Tuvalu storage system

Please, tell me about it!

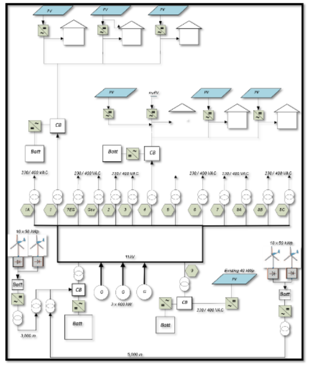
Table 4-1 Existing Key Power Systems

Atoll	Existing Power Systems	Age	Existing distribution network	Net generation (kWh)	Fuel Consumed (1000 l)
Funafuti	3 600kW Generator Sets	Dec 2006	11KV and 230/400V AC networks	4,997,500	1,423
Nanumea	3 generator sets	Dec 1999	230/400V AC Network	110,280	45
Nanumaga*	3 generator sets	Dec 1999	230/400V AC Network	115,000	45
Niutao*	3 generator sets	Jan 2000	230/400V AC Network	110,000	49
Nui*	3 generator sets	Nov 1999	230/400V AC Network	120,000	47
Vaitupu	3 generator sets	Nov 1999	11KV and 230/400V AC networks	293,876	81
Nukufetau*	3 generator sets	Nov 1999	230/400V AC Network	120,000	42
Nukulaelae*	3 generator sets	Oct 1999	230/400V AC Network	70,000	31
Niulakita			No island network		
Diesel Total				**5,936,657**	**1,763**
Vaitupu	46 kWp hybrid PV/battery/diesel	2009	230/400 VAC	69,800	-
Funafuti	40kWp PV array	2008	230 / 400 VAC	60,400	-
Funafuti	42kWp PV array	2012	230 / 400 VAC		
Funafuti	66kWp PV array associated with desalination plant	Under construction	Note. This plant is not yet installed		
Funafuti	9 kWp PV array	2012	Standalone		
PV Total				**130,200**	

*Estimated energy values

Source: Tuvalu Electricity Corporation

Figure B-4 Stage 3, Decentralised, synchronised PV Clusters on Funafuti, PV solar and grid-connected Wind power.



TEC staff installing a non-metallic, low maintenance and cyclone proof demonstration solar roof

Battery Controls in Vaitupu (SMA)

Battery Bank in Vaitupu

Source: https://www.tectuvalu.tv/wp-content/uploads/2021/09/Tuvalu_C3.pdf

Specificity of solar micro grids in island areas

THANK YOU FOR YOUR ATTENTION

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