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

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Specificity of solar micro grids in island areas

Government of Tonga / PCREEE / ISA / INES PFE

SESSION 3
Materials selection

Micro-grid in Corsica named « Myrte »

Specificity of solar micro grids in island areas

SESSION 3: How to select PV components adapted to the Pacific context?

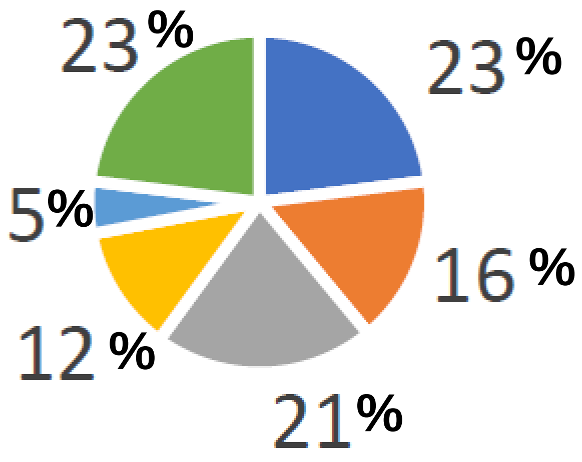
(Olivier VERDEIL)

- Costs distribution of a micro grid
- Key decision-making rule-of-thumb
  - ➔ Choice of mounting structure
  - ➔ Choice of photovoltaic modules
  - ➔ Choice of inverter and regulator
  - ➔ Choice of storage system
- Case-study : Request for proposal to Pitcairn Island
- Resilience and robustness of components in the light of the Pacific salty & windy context (see “Solar under storm recommendations” from Rocky Mountain Institute)

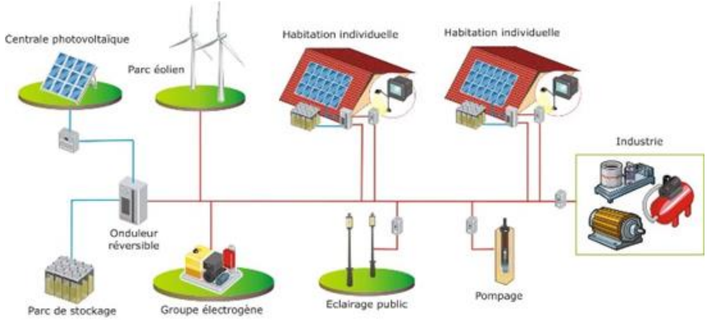
Specificity of solar micro grids in island areas

Costs distribution of a micro grid

The graph shows the costs distribution according to **six main components** of a solar / diesel micro-grid (one size around 40 kW).



- PV solar panels
- PV cables, charge controllers, DC / AC conversion
- Storage
- Distribution and meters
- Emergency diesel generator
- Other costs



Results of a survey carried out on 27 micro-grids (solar and hybrid) in Sub-Saharan Africa from 2013 to 2015.

Specificity of solar micro grids in island areas

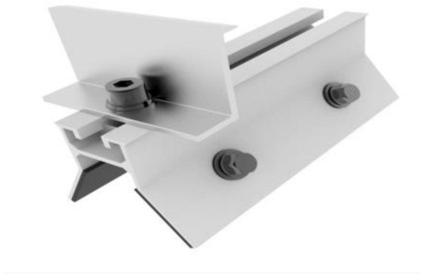
Costs distribution of a micro grid

COSTS	Low	Medium	High	Lifetime
Installed PV costs (USD / kWp)	1400	1700	2000	20-25
Lead-acid battery costs (USD / KWh)	200	350	500	3-7
Lithium-Ion battery costs (USD / KWh)	400	800	1200	8-15
Inverter & charge controller costs (USD / KWh)	600	900	1200	8-12
Operations & maintenance costs (USD)	2% of capital expenditure for PV panels and inverters			/
Discount rate (%)	8	10	12	/

Specificity of solar micro grids in island areas

Key decision-making rule-of-thumb / Norm & choice of mounting structure

<u>General characteristics for</u>
<u>PV installation fixed on the roof:</u>
(steel or fiber cement deck)

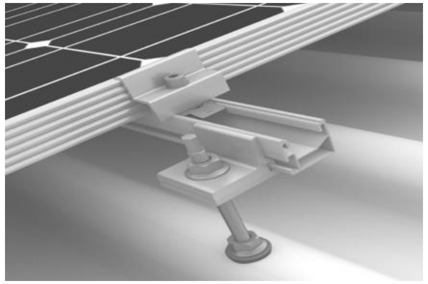


Rider

\+ light solution fixed with opposing screws
\- fixed only on the steel deck

Mini rail

\+ light solution & fixation on 2 waves of the steel deck
\- fixed only on the steel deck



Long rail

\+ very stable solution fixed to the frame with hanger bolts
\- slower solution to implement

Need to check if the **building can support the weight of the PV installation** and if the manufacturer of the fixing solution **guaranteed to withstand local winds** !!!

Specificity of solar micro grids in island areas

Key decision-making rule-of-thumb / Norm & choice of mounting structure

General characteristics for PV installation fixed to the ground:

Box weighted with earth or stone

+ local ballast materials
- not very aesthetic

Ciment foundation

+ very stable solution
- requires delivery of cement

Metal pillar sunk into the ground

+ relatively simple dismantling and almost no impact on the environment
- requiring specific machines

Screw pile

Pile to strike

Need to make a **study of the type of the ground** and check that the manufacturer of the fixing solution **guarantees resistance to local winds** (with ballast calculation) !!!

Specificity of solar micro grids in island areas

Key decision-making rule-of-thumb / Norm & choice of mounting structure

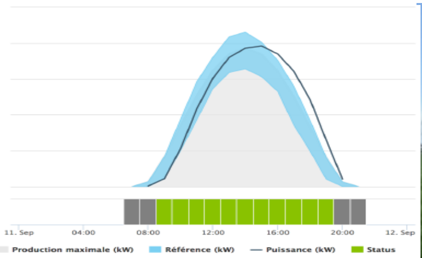
General characteristics for PV tracker solution:

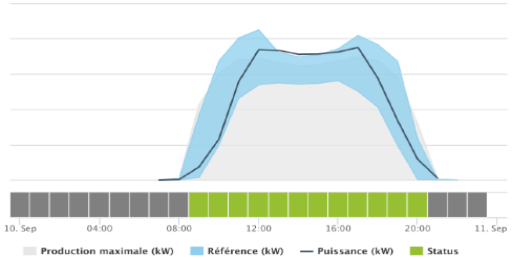
increase production by approximately:

1 axis tracker (+ 10%)

1 and a half axis tracker (+ 20%)

2 axis tracker (+30%)

But the investment is more substantial (around 20% to 30%) and requires serious maintenance

Need to calculate the **spacings between the trackers to avoid shading** and check that the manufacturer of the fixing solution **guarantees resistance to local winds** (with ballast calculation and **automatic management** of the return to the **safety position** in the event of a storm) !!!

Specificity of solar micro grids in island areas

Key decision-making rule-of-thumb / Norm & choice of mounting structure

General characteristics for floating PV installation:

Need to take into account the **water level evolution** according to the seasons and to make a precise **study of the anchor points** on the banks !!!

Specificity of solar micro grids in island areas

Key decision-making rule-of-thumb / Norm & choice of mounting structure

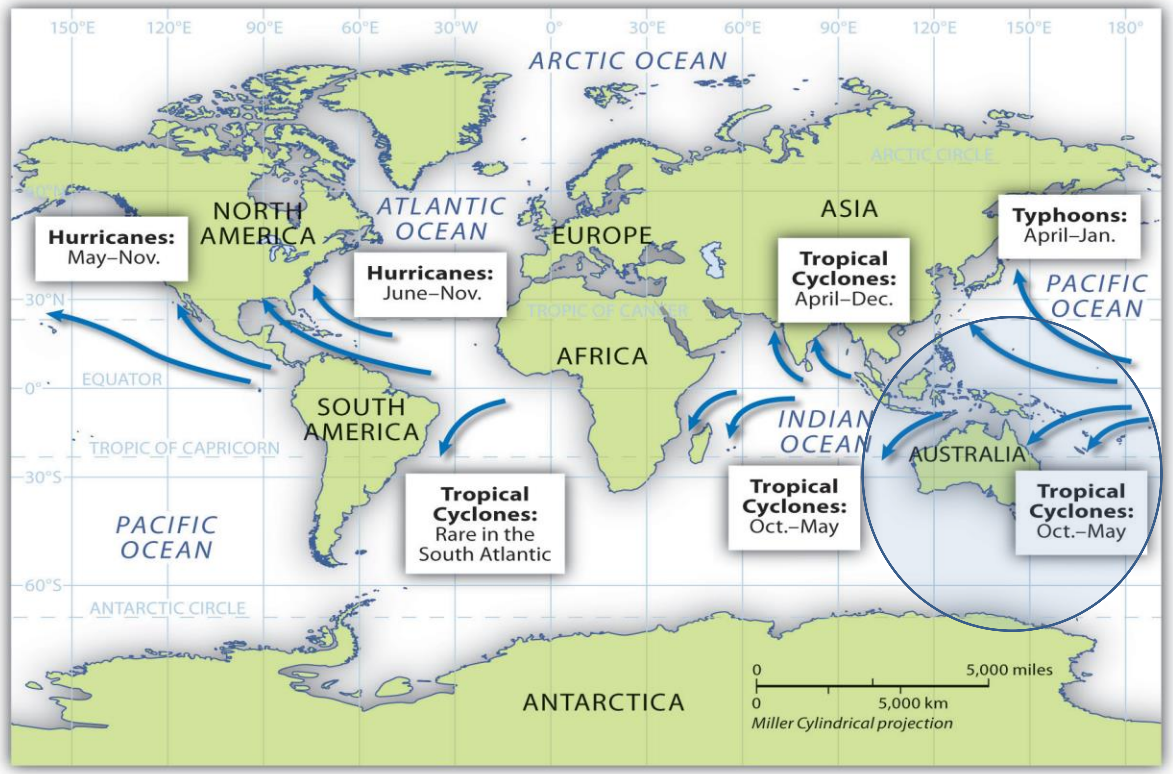
General characteristics for agrivoltaic:

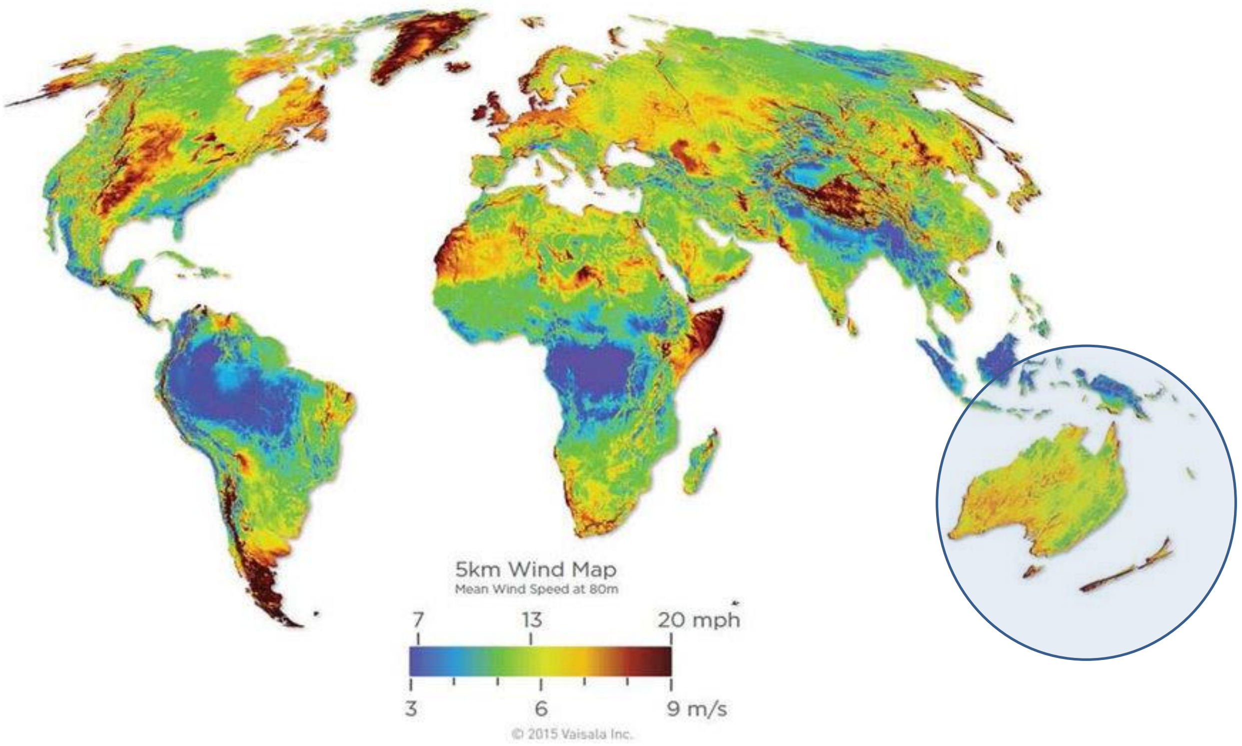
Need to make a study of the **agricultural constraints** and check that the manufacturer of the fixing solution **guarantees resistance to local winds** (with ballast calculation) !!!

Specificity of solar micro grids in island areas

Key decision-making rule-of-thumb / Norm & choice of mounting structure

Cyclones / Typhoon / Hurricane period:





Specificity of solar micro grids in island areas

Key decision-making rule-of-thumb / Norm & choice of mounting structure

<u>Classification scale for the tropical cyclones intensity</u> (Saffir-Simpson scale)

Category	Wind Speed (mph)	Damage at Landfall	Storm Surge (feet)
1	74-95 *119 - 153 km/h*	Minimal	4-5 *1,2 – 1,5 m*
2	96-110 *154 - 177 km/h*	Moderate	6-8 *1,8 – 2,4 m*
3	111-130 *178 - 210 km/h*	Extensive	9-12 *2,7 – 3,7 m*
4	131-155 *211 - 251 km/h*	Extreme	13-18 *4 - 5,5 m*
5	> 155 *more than 251km/h*	Catastrophic	19+ *more than 5,5 m*


Ouragan Noel (2007)


Ouragan Irene (2011)


Ouragan Katrin (2005)

Specificity of solar micro grids in island areas

Key decision-making rule-of-thumb / Norm & choice of PV modules

General characteristics of PV modules:

⇒ **Type of technology** (amorphous, polycrystaline, mono-crystalline, heterojunction, bi-facial, half-cell ...)

⇒ **Efficiency** (>18%) and **electrical characteristics** (Wp, Voc, Vmpp, Isc, Impp)

⇒ **Sensitivity to different types of solar radiation** (direct, diffuse, albedo)

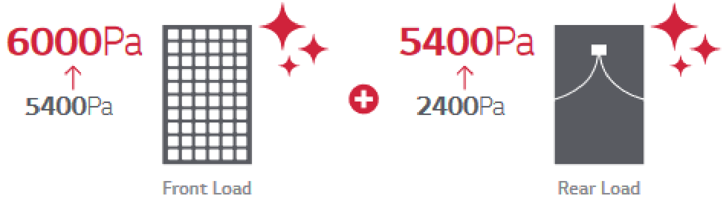
⇒ **Thermal coefficient** (Power-Voltage-Current / Temp.)

⇒ **Resistance to climatic conditions** (Panel Front Load > 6,000 Pa, Panel Rear Load > 5,400 Pa)

⇒ **Connector type** (Staübli-Multiconact, Sunclic, Tyco, Amphenol, Hirschmann, …)

⇒ **Number of bypass diodes** (minimum 3 if 60 whole cells)

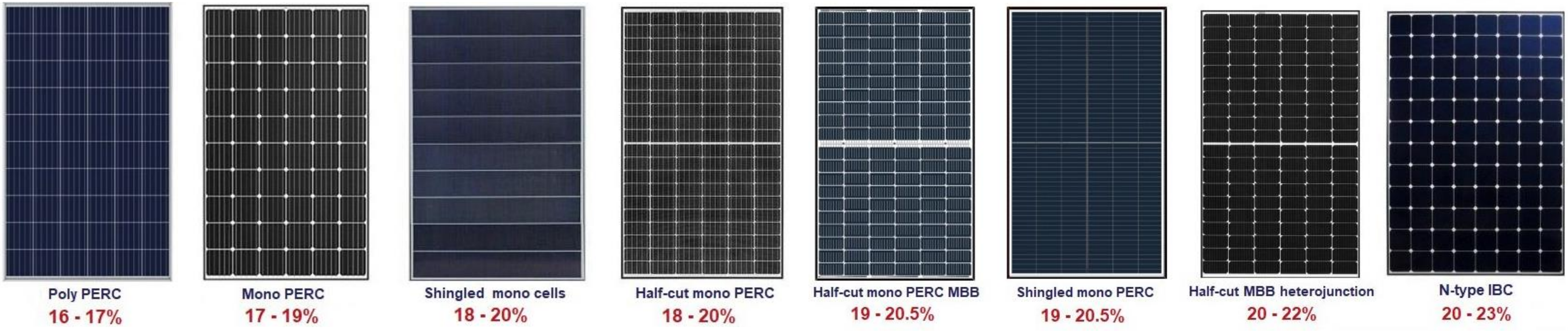
⇒ **Protection class** (class II)



Specificity of solar micro grids in island areas

Key decision-making rule-of-thumb / Norm & choice of PV modules

Best PV cells technology and their efficiency:



Source: cleanenergyreviews.info

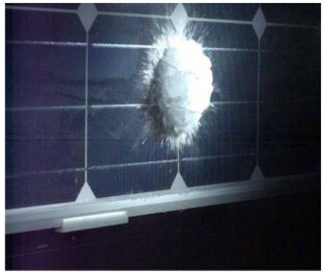
MBB = Multi-Bus-Bar (Wire)
IBC = Interdigitated Back Contact
PERC = Passivated Emitter and Rear Cell
SHINGLE = Shingle solar cells are solar cells which are cut into typically 5 or 6 strips
BSC = Bifacial Solar Cell is a photovoltaic solar cell that can produce electrical energy when illuminated on both its surfaces
NTYPE = N-Type tends is a better choice due to reducing LID (Light Induced Degradation) & increase durability and performance compared to p-type

Specificity of solar micro grids in island areas

Key decision-making rule-of-thumb / Norm & choice of PV modules

IEC 61215	**Crystalline PV modules** testing (Design Quality, tested **suction load** (Ex. 2400 Pa) and **overload** (Ex 5400 Pa))
IEC 61646	Testing of **thin film PV modules** (Manufacturing quality)
IEC 61701	**Salt mist corrosion test**
IEC 61730	Qualification for **operational safety** (application class, protection class II)





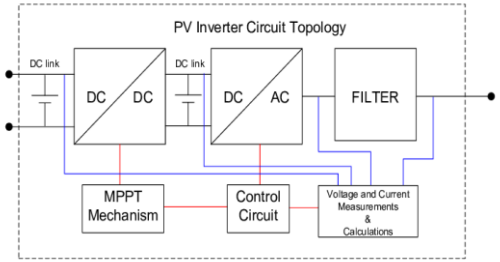


Specificity of solar micro grids in island areas

Key decision-making rule-of-thumb / Norm & choice of PV inverters




General characteristics of PV inverters:



⇒ Wide input voltage range and MPPT range (ex: 150 to 600 V)

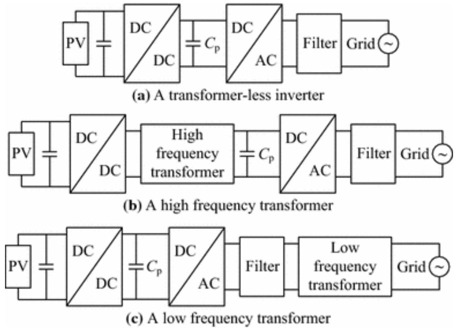
⇒ Maximum power point search quality and accuracy (MPPT) with one or more MPPT

⇒ Maximum power limitation by mismatching Pmax

⇒ Overvoltage protection (varistors)

⇒ Protection of people (DC insulation control)

⇒ With or without transformer (TL: transformerless)



⇒ High efficiency at the usual power level of the installation (ex: 92% to 98.5%)

⇒ Low consumption & noise level

⇒ Low electromagnetic disturbances & harmonic levels

Specificity of solar micro grids in island areas

Key decision-making rule-of-thumb / Norm & choice of PV inverters




<u>General characteristics of inverters:</u>

⇒ Display of the operating parameters (indicator lights, displays, etc.)

⇒ Data recording (accessible by computer link)

⇒ Good reliability, extended and extendable warranty period

⇒ Degree of protection (eg IP65)

⇒ Load management and storage management

⇒ Electricity network management (active power regulation, reactive power supply)

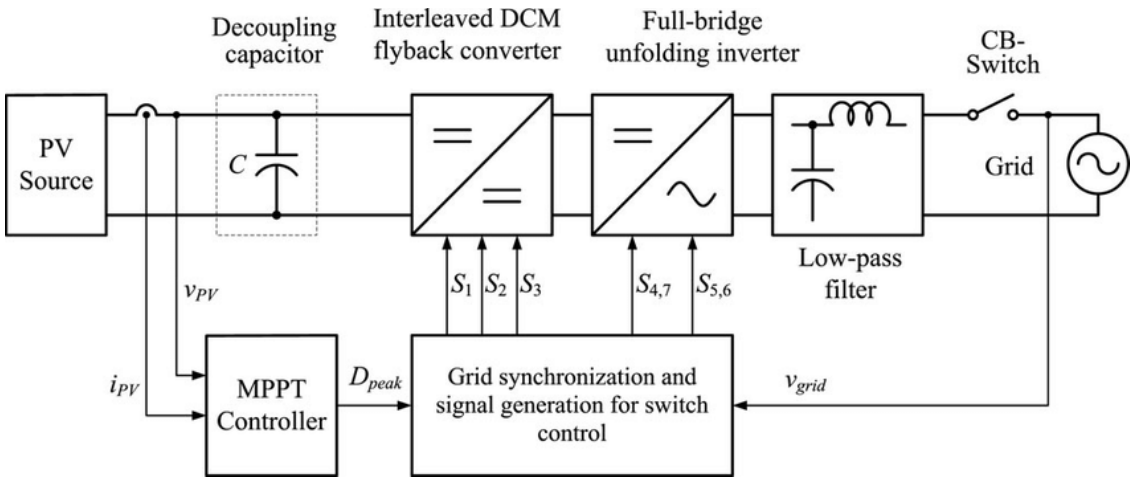
⇒ Perfect synchronization with the network and zero or low phase shift (power factor = 1)

⇒ Automatic network decoupling (<20 ms) if out of tolerance

Specificity of solar micro grids in island areas

Key decision-making rule-of-thumb / Norm & choice of PV inverters

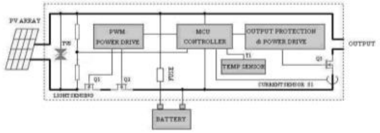
IEC 62109-1 / 2	**Safety of energy converters for use in PV systems**
IEC 62116	Interconnected PV inverters - **test procedure for prevention of islanding**
IEC 61727 **VDE 0126-1-1**	Electrical network interface **Decoupling protection**
IEC 61000-3-2	Harmonies



Specificity of solar micro grids in island areas

Key decision-making rule-of-thumb / Norm & choice of PV regulators

General characteristics of regulators:



⇒ Type of regulator:

- Classic regulator (connects the modules to the battery)
- MPPT regulator (converts voltage from generator to battery)

⇒ Different internal functioning:

- Shunt regulator (most used technology)
- Regulator Series

⇒ Different current regulations:

- All or nothing regulation (old, low cost)
- PWM regulator (more precise current management)

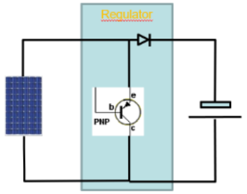
⇒ Different commands:

- Regulation by voltage threshold
- Software regulation, self-learning "fuzzy logic" concept

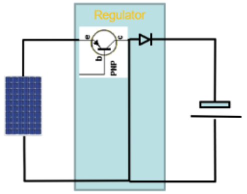
⇒ Very useful additional functions:

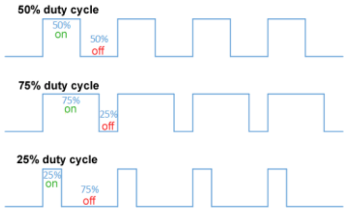
- Battery status indicator (with optional separate voltage measurement), Thermal compensation, Timed load shedding
- Adjustable cut-off thresholds (charge and discharge), Data logging with shunt

SHUNT regulator
Current regulation by switching on the module



SERIES regulator
Current regulation by open circuiting of the module





Specificity of solar micro grids in island areas

Key decision-making rule-of-thumb / Norm & Choice of Storage system

0	0	2	2	2	2	2	3	3	4
direct		mechanical static	mechanical dynamic	electrochemical			thermic		thermo chemical
capacitor	superconductor air torus	a) pump-fed power station (h=300m)	storage gyroscope	LT batterie	HT batterie	H_2/O_2 - fuel cell	hot water	PCM - device	H_2/O_2 motor
$d = d' = 1\mu m$; 100 V, $\varepsilon_r = 100$; $\rho = 2\ kg/m^3$	$B = 10$ Tesla; $\mu_r = 1$; $\rho = 2\ kg/m^3$	b) air pressure	7000 min^{-1}	1) $Pb/PbO_2/H_2SO_4$; 2) Zn/NiO_2; 3) $Zn/Cl_2 \cdot 6H_2O$	1) Na/S (320°); 2) Li(Al)FeS; (450°C)	a) stored H_2/O_2; b) just H_2 in FeTi	$\Delta t = 70°C$; $\eta = 19\%$	a) water steam (100 bar); b) LiF / NaF - melt	H_2/O_2 stored; $\eta = 25\%$

Ex: Super-Capacitor
for reactive energy compensation

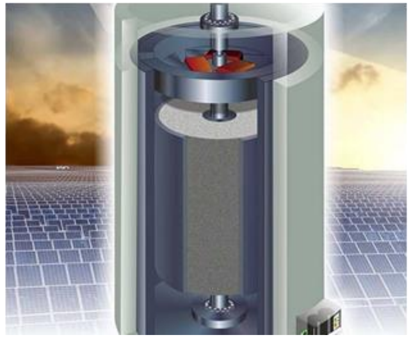
Ex: STEP
Pumping-Turbining
Energy Transfer Station

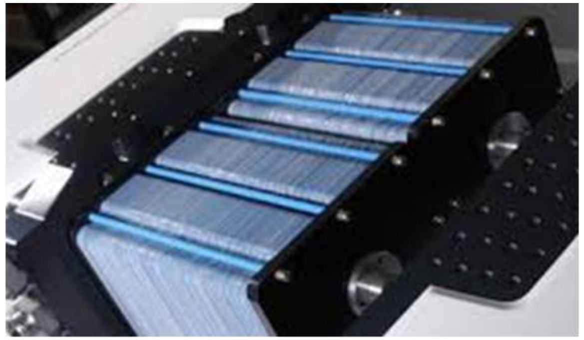
Ex: Flywheel

Ex: Hydrogen fuel cell

Ex: Latent heat

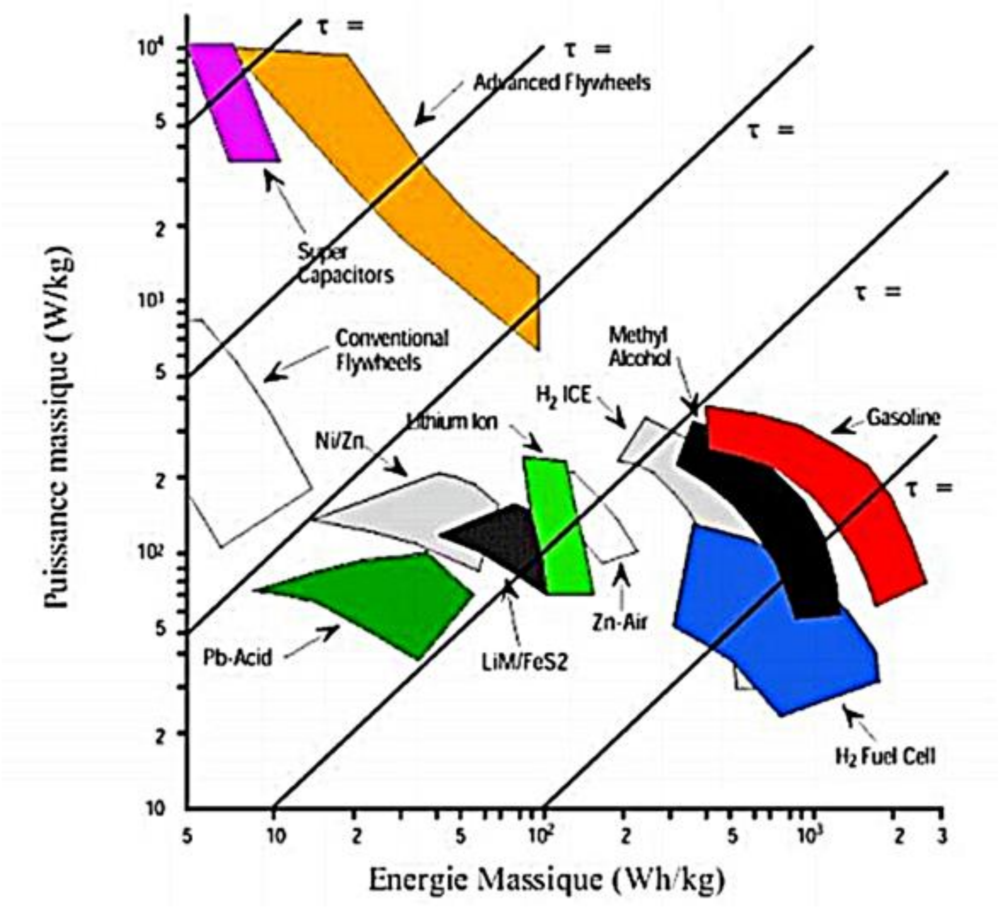
Ex: Energy Storage
compressed air





Specificity of solar micro grids in island areas

Key decision-making rule-of-thumb / Norm & choice of storage system

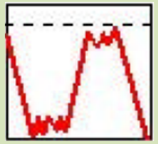


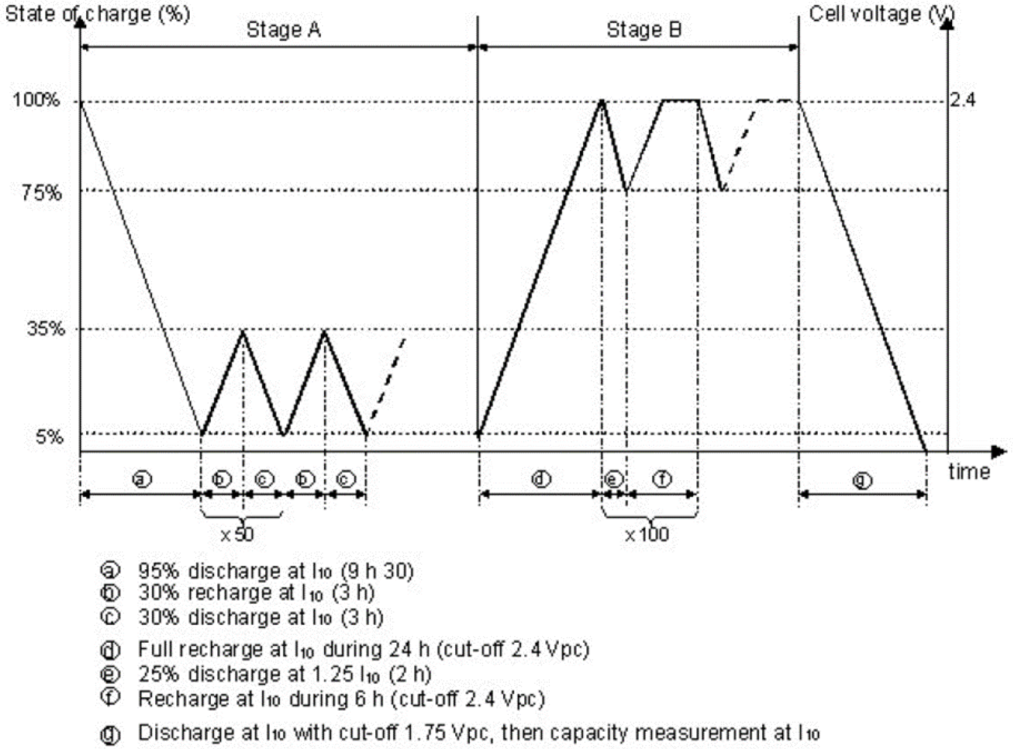
Need to choose the right battery according to its power & energy needs and its field of application !

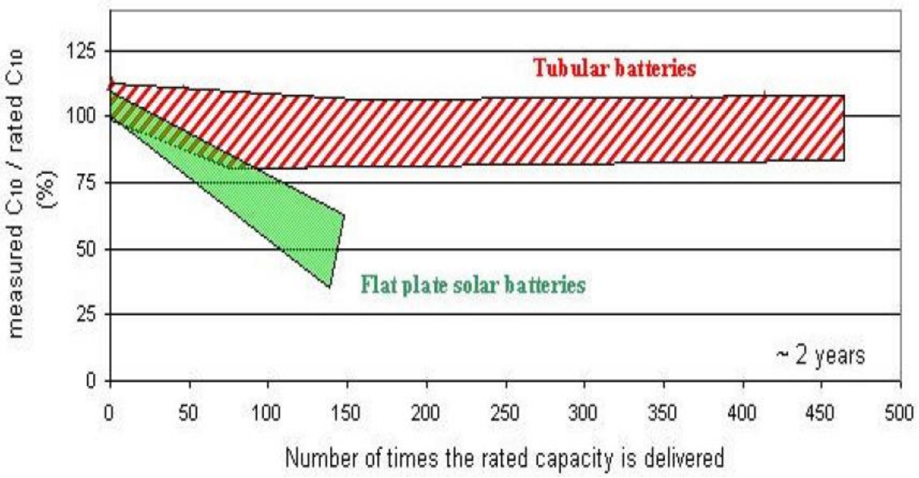
Specificity of solar micro grids in island areas

Key decision-making rule-of-thumb / Norm & choice of storage system

IEC 61427







Specificity of solar micro grids in island areas

Key decision-making rule-of-thumb / Norm & choice of storage system

Electro-chemical storage

Lead acid	Nickel	Lithium
Opened	Ni-Cd	Li-ion
Valve regulated (AGM / GEL)	Ni-MH	Li-metal

Li-ion:
- LCO
- NCA
- LMO
- NMC
- LFP
- …

Specificity of solar micro grids in island areas

Key decision-making rule-of-thumb / Norm & choice of storage system

Lead acid
Good value for money,
wide range of capacities
Heavy and bulky, contain lead / acid
Stationary applications
40 Wh / kg & ≥ 200 USD / kWh

Opened battery (with maintenance)
(Liquid electrolyte + cap for filling)
→ OPzS
Flooded/tubular-plate/stationary

Sealed battery (without maintenance)
(VRLA: Valve Regulated Lead Acid)

- AGM: Absorbed Glass Mat
(frozen electrolyte)
- GEL
(gelled electrolyte) → OPzV
Sealed/tubular-plate/stationary

Nickel Cadmium
Flexible in its use by rapid charges
Accepts extreme temperatures
Has a high discharge current
Good resistance to deep discharges
Cadmium toxic compound
60 Wh / kg & ≥300 USD / kWh

Nickel Metal Hydrid
Low toxicity and recyclable
High power applications required
Accepts extreme temperatures
Sensitive at the end of charging requiring a specific charger
Self-discharge is quite important (30% / month)
80 Wh / kg & ≥ 350 USD / kWh

Lithium Ion → LFP
Lithium Iron Phosphate

Mobile application and good lifespan
High power applications required
Implementation is quite tricky in charging and discharging
High cost for off-grid energy applications
150 Wh / kg & ≥ 400 USD / kWh

Specificity of solar micro grids in island areas

Key decision-making rule-of-thumb / Norm & choice of storage system

Zinc-Air Battery (Zn-Air)

High specific energy
Abundant and low cost materials & Recyclability
Industrial scale up to be proven
Low efficiency & Low cyclability
225 Wh / kg & ≥ 350 USD / kWh

Sodium Battery (VRB vanadium, $Zn\text{-}Br_2$)

Good energy density
Abundant and inexpensive materials,
High temperature (thermal losses to be compensated)
Danger of liquid sodium
125 Wh / kg & ≥ 450 USD / kWh

Redox Battery (Na-S, Zebra $NaNiCl_2$)

Possibility of decoupling energy and power
100% of the capacity can be used,
High costs
Complex system (auxiliaries)
Self-discharge
40 Wh / kg & ≥ 500 USD / kWh

Redflow $Zn\text{-}Br_2$ system (300 kW / 660 kWh; container de 20 feet, 25 t)

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Specificity of solar micro grids in island areas

Case-study : Pitcairn Islands

Request for proposal / Supply, install and local training for the Solar PV Hybrid System of Pitcairn Islands (Page 5 & 6)

Evaluation Criteria, Competency Requirements		Score Weight (%)	Points Obtainable
(1) Adherence and compliance with the components specifications, standards and warranty requirements	a) Monocrystalline Solar Module, Rated power 450Wp or higher and module efficiency 20 % or higher	10	70
	b) Valve Regulated Lead Acid Battery	10	70
	c) Energy Management System and Balance of System	10	70
	d) Distribution line upgrade	10	70
(2) Design Adequacy and Project Experiences as the main contractor in RE hybrid systems for minigrid applications – solar and energy storage - of comparable scale to the proposed contract	a) Adequacy of proposed system design and configuration	10	70
	b) Proven experience as the main contractor in the deployment of grid-connected solar PV systems and RE hybrid systems for minigrid applications – solar and energy storage of comparable scale to the proposed contract	10	70

(3) Adequacy of proposed implementation plan, timeline and training plan	a) Relevant training program of local stakeholders to ensure overall system sustainability	10	70
	b) Adequacy of proposed implementation plan and timeline	5	35
(4) Ability to provide Service Center to cater to repair and troubleshooting services after handover	a) Guarantee period for System performance, Components and equipment	10	70
	b) Adequacy of proposed maintenance and support services agreement	5	35
(5) Personnel qualifications- Compliance with the required expertise and skill sets according to TOR of key personnel dedicated for the project			70
	Total score	**100%**	**700**
	Qualification score	**70%**	**490**

Specificity of solar micro grids in island areas

Case-study : Pitcairn Islands

Request for proposal / Supply, install and local training for the Solar PV Hybrid System of Pitcairn Islands (Page 19)

The mounting structure should meet the following specification and requirement:

⇒ Material of mounting structure: Hot deep galvanized steel
⇒ Wind load requirement: 40 meter per second (150km/h)

The solar PV module should meet the following specification and requirement:

⇒ The total capacity of solar PV array: minimum 134kWp
⇒ Minimum Performance at Standard Test Condition(STC) of PV module (1000W/m_2, 25±2°C, AM 1.5)
⇒ Nominal power of solar PV module at MPP(Maximum Power Point) : minimum 450Wp
⇒ Efficiency of solar PV module: minimum 20% (Monocrystalline)
⇒ Annual performance degradation: 0.6% each year.
⇒ Module performance warranty: minimum 92.6% of the nominal power upto 10 years and minimum 83.6% upto 25 years

Specificity of solar micro grids in island areas

Case-study : Pitcairn Islands

Request for proposal / Supply, install and local training for the Solar PV Hybrid System of Pitcairn Islands (Page 19)

The battery storage should meet the following specification and requirement:

⇒ Nominal capacity of battery storage: minimum 1,594kWh
⇒ Nominal battery voltage: 300V
⇒ Type of battery storage: VRLA(Valve Regulated Lead Acid), maintenance-free type
⇒ Cycling performance: 2,400 cycles or higher at 60% depth of discharge at 20 degree Celsius
=> Battery shall be packed in metal rack

The battery charger:

⇒ Max. Efficiency : > 90 % , Stand-by loss : < 3% & Acoustic noise < 65 dBA
⇒ Electrical input: 3 phase, 400V±10%, 50/60Hz & Electrical output: 100kW, 250-350Vdc, overload 125%/10min
⇒ Charging function: CC & CV mode, Floating , Absorption & ~~Equalizing charging~~

Specificity of solar micro grids in island areas

Case-study : Pitcairn Islands

Request for proposal / Supply, install and local training for the Solar PV Hybrid System of Pitcairn Islands (Page 19)

DC/DC Converter for PV:

⇒ MPPT control of PV array, floating charging & Output power limiting at the full state of charge (SOC)
⇒ Electrical input: 300~450Vdc & Electrical output: 40kW, 270-350Vdc

CVCF Inverter (UPS):

⇒ Max. Efficiency : > 90 % and Stand-by loss : < 3%, Acoustic noise < 65 dBA
⇒ Electrical input: 250~450Vdc & Electrical output: 3 phase, 150 kVA, 400/230Vac, 50±0.1Hz, Overload : 125%/10min, 150%/30sec

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Specificity of solar micro grids in island areas

Resilience and robustness of components in the light of the Pacific salty & windy context

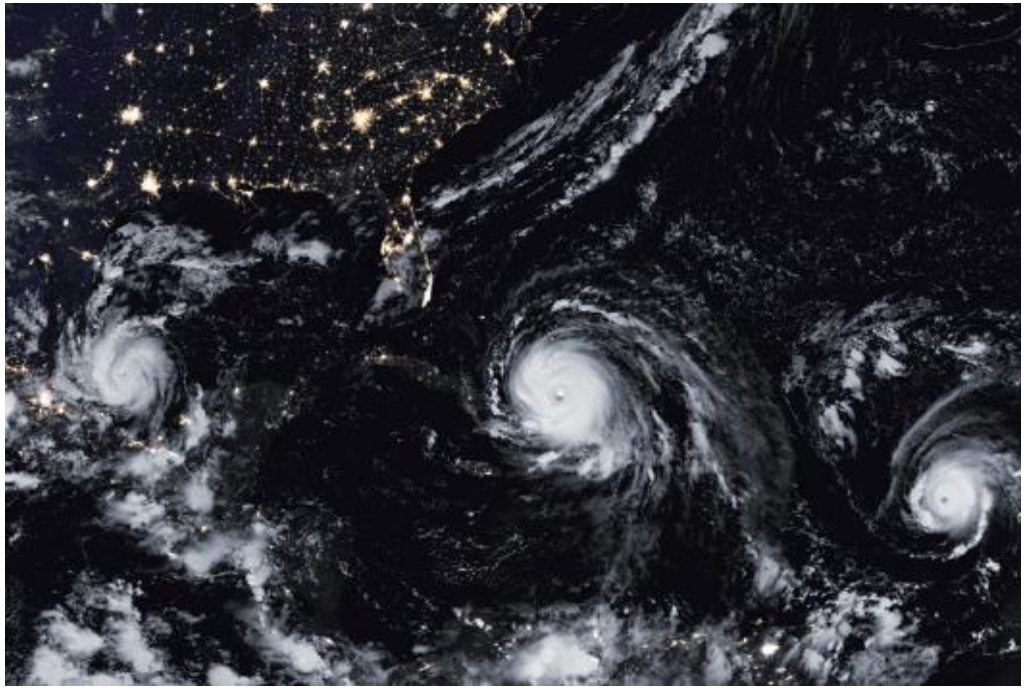


Photo courtesy NASA Earth Observatory

Photo by Kenneth Wilsey for FEMA - Humacao, Puerto Rico, Jan. 25, 2018

Photo by Kenneth Wilsey – Feb 13, 2018 Guaynabo, Puerto Rico

SOLAR UNDER STORM (from ROCKY MOUNTAIN INSTITUTE)
SELECT BEST PRACTICES FOR RESILIENT GROUND-MOUNT
PV SYSTEMS WITH HURRICANE EXPOSURE
BY CHRISTOPHER BURGESS AND JOSEPH GOODMAN

and a guarantee of good implementation

Specificity of solar micro grids in island areas

Resilience and robustness of components in the light of the Pacific salty & windy context

RECOMMENDATIONS FOR BUILDING MORE RESILIENT SOLAR PV POWER PLANTS (specifications in “Solar Unter Storm” from Rocky Mountain Institut):

⇒**Require high-load PV modules** (up to **5,400 Pa** uplift) , based on structural calculations

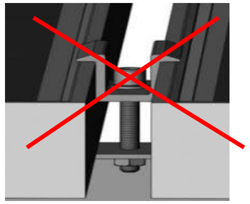
⇒**Require structural engineering** in accordance with **norms** and **site conditions** (wind forces), and **attachment design** (ground-mount foundation).

⇒ **Require to confirm with manufacturer** that **actual site conditions** are **in accordance with their base condition assumptions from wind-tunnel testing**.

⇒**Require very good manufacturer quality of the supporting structure fixing bolts** (Quality Assurance and Quality Control process).

⇒Require a **good implementation of the supporting structure fixing** and a **bolt** hardware **locking solution**.

⇒Provide **fixing of the modules** with a **bolt passing through the frame** of the module. Otherwise, only require T-Clamps if they hold the modules individually or independently.



and a guarantee of good implementation

Specificity of solar micro grids in island areas

Resilience and robustness of components in the light of the Pacific salty & windy context

RECOMMENDATIONS FOR BUILDING MORE RESILIENT SOLAR PV POWER PLANTS (specifications in “Solar Unter Storm” from Rocky Mountain Institut):

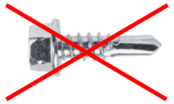
⇒Require **structural engineering** in accordance with the **lateral solicitations on the supporting structures and on the electrical boxes** (exposed to strong winds)

⇒**Require dual post fixed tilt ground mounts**, which significantly reduce foundation failure risk.

⇒**Do not recommend trackers** for projects **in Category 4 or higher wind zones**.

=> Require all **hardware be sized based on 25 years** (or project life) **of corrosion**.

=> **Do not recommend any self-tapping screws**.



Specificity of solar micro grids in island areas

Resilience and robustness of components in the light of the Pacific salty & windy context

<u>RECOMMENDATIONS FOR BUILDING MORE RESILIENT SOLAR PV POWER PLANTS:</u>

⇒ **Require the right choice of materials to limit fixing frame oxidation: prefer aluminum, highly galvanized steel, 316 stainless steel!**

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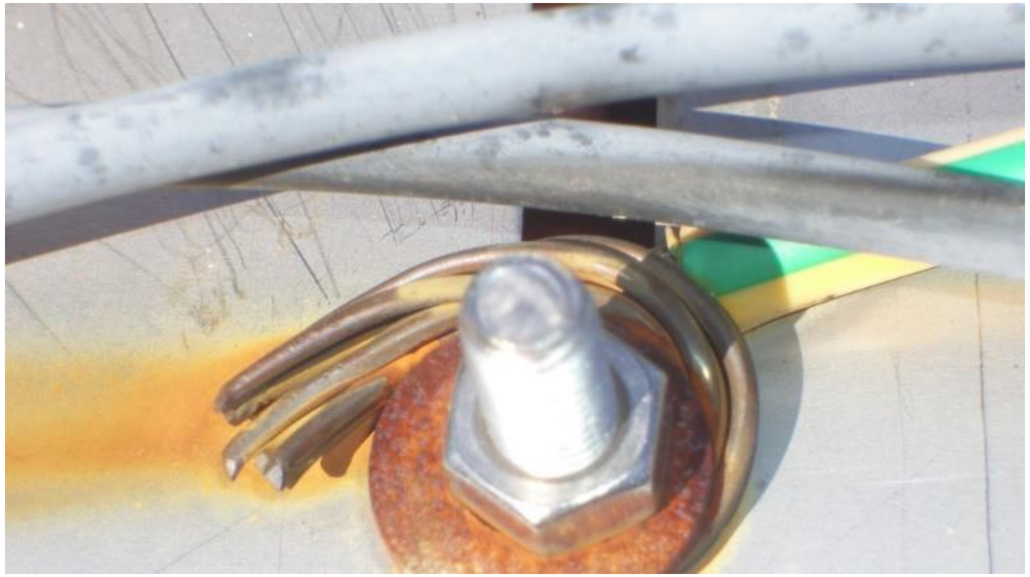
<u>RECOMMENDATIONS FOR BUILDING MORE RESILIENT SOLAR PV POWER PLANTS:</u>

⇒ **Require the right choice of materials to limit oxidation from equipotential bonds: pay attention to the electrolytic couple !**

bi-metal washer



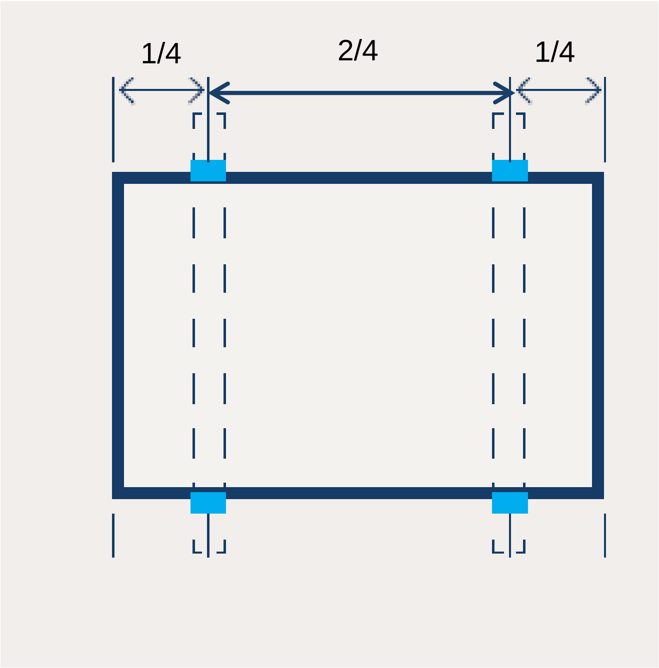
classic washer

Specificity of solar micro grids in island areas

Resilience and robustness of components in the light of the Pacific salty & windy context

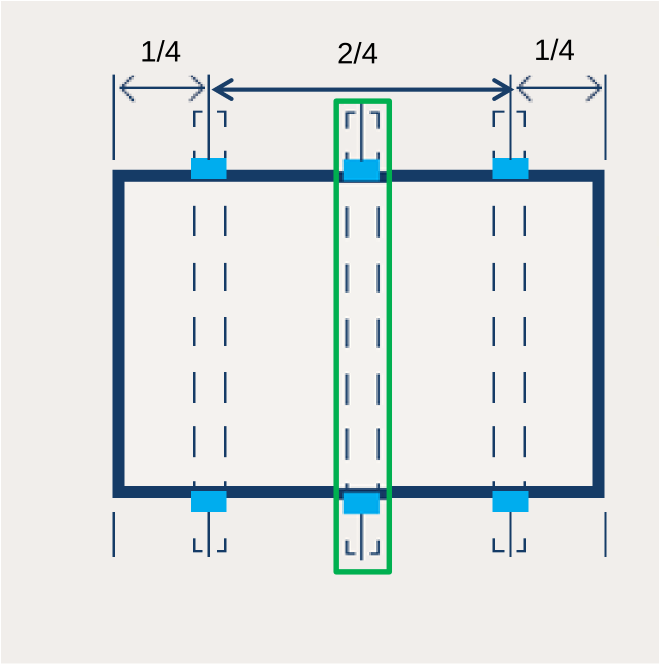
<u>RECOMMENDATIONS FOR BUILDING MORE RESILIENT SOLAR PV POWER PLANTS:</u>

⇒ **Make sure that the installation teams will respect the manufacturer's recommendations**



Standard mounting specifications

No respect of the mounting specifications !!!!



In cyclonic areas: 3 rails are recommended

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<u>RECOMMENDATIONS FOR BUILDING MORE RESILIENT SOLAR PV POWER PLANTS:</u>

⇒ **Make sure that the products chosen correspond to the climatic conditions of the site**

Low resistance "C" or "I" type profile !!!

Bolts not strong enough !!!

In cyclonic areas: tubular structures and triangular reinforcements are recommended on all axes

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<u>RECOMMENDATIONS FOR BUILDING MORE RESILIENT SOLAR PV POWER PLANTS:</u>

⇒ **Make sure that the products chosen correspond to the climatic conditions of the site**

In cyclonic areas: it is recommended to surround the PV installation with a mesh fence
(in addition to the anti-theft protection, it is a good way to attenuate turbulence and to stop flying objects)

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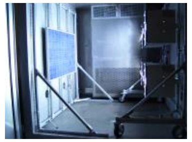
<u>BEST PRACTICES:</u>

⇒ **Know very well the site of a micro-grid project**
(make a study of the ground and of local climatic conditions)

⇒ **Always obtain a validation from manufacturers of PV modules and fixing structures that their systems are perfectly designed to all the constraints of the site**
(wind category, aggression of UV solar radiation and salty atmosphere)



⇒ **Check that the installation teams will apply all the manufacturers installation recommandations**
(compliance with electrical and mechanical assembly plans, tightening torques and locked fixings)

Specificity of solar micro grids in island areas

THANK YOU FOR YOUR ATTENTION

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Online Training – November 2021

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