Seven proven ways to improve LCoE in PV and Storage

New Gamesa Electric Proteus PV & BESS Inverters

inter solar award 2022 FINALIST

PV Magazine & Gamesa Electric

Webinar May 3rd 2022 – 15:00 (CET +2)

Enrique de la Cruz
Sales Director PV & Storage

Antonio Montoto
Sales Manager Hybrid & BESS

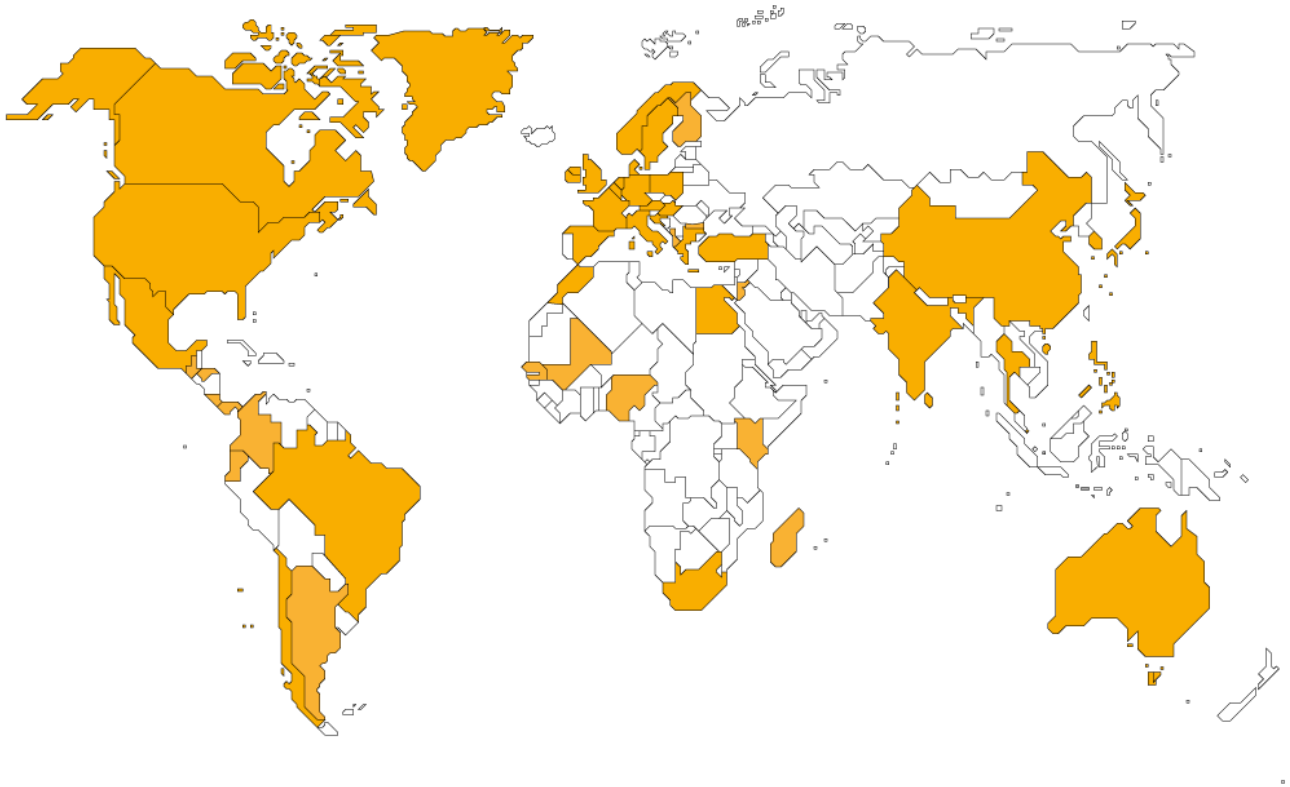
GamesaElectric

Gamesa Electric

A 100% Siemens Gamesa Renewable Energy company

With a worldwide installed capacity of over 118 GW, Siemens Gamesa Renewable Energy is a **global technological leader in the wind industry** with **a presence in more than 90 countries.**

Its end-to-end value chain expertise encompasses onshore and offshore wind turbine design, manufacturing, installation as well as cutting-edge service solutions.



Globally Installed (Sep 21)	120 GW
GW under Service (Sep 21)	79.2 GW
Order Book (Sep.21)	€ 32.5 B
Annual Revenue (Sep 21)	€ 10.2 B
Employees (Sep 21)	26,182
Worldwide presence	>50 sales offices in 39 countries

Albania
Argentina
Australia
Brazil
Bulgaria
Canada
Chile
China
Colombia
Costa Rica
Czech Rep.
Ecuador
Egypt
Finland
France
Germany
Greece
Guatemala
Honduras
India
Ireland
Italy
Japan
Jordan
Kenya
Madagascar
Mali
Mexico
Morocco
Nigeria
Norway
Panama
Philippines
Poland
Puerto Rico
Senegal
South Africa
Spain
Sri Lanka
Sweden
Turkey
UK
Uruguay
USA

Our facilities, our credentials

Shaping new energy

>4 GW *	>29 GW *	8	>900	268 MM€
Solar inverters	Wind converters	Production centers	Employees worldwide	Turnover FY2020

Spain

Bilbao

Headquarters

Reinosa


Wind Power


Hydroelectric


Diesel & Gas


Marine Propulsion

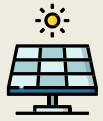

Permanent Magnets

Valencia


Wind Power

Madrid


Wind Power


Photovoltaic


E. Storage


Power Quality


Drives & Converters

Brazil

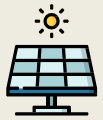
Camaçari


Wind Power

India

Nellore


Wind Power


Photovoltaic

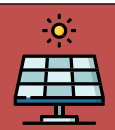
China

Tianjin


Wind Power

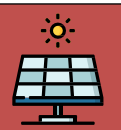
Dedicated Sales teams

USA


Photovoltaic


E. Storage

Australia


Photovoltaic


E. Storage

(*) Cumulative Wind data at FY2020 closure (September 2020). Cumulative Solar PV data at Q1 2021

Product Overview

GamesaElectric Shaping new energy

Gamesa Electric Proteus

Power Converters

Gamesa Electric Proteus PV
Gamesa Electric Proteus PCS
Gamesa Electric Proteus HYBRID

Gamesa Electric Proteus DC-DC Converter

Power Stations

Gamesa Electric Proteus PV Station
Gamesa Electric Proteus HYBRID Station
Gamesa Electric Proteus PCS Station

Prebuilt Skids for batteries

Gamesa Electric STOR Skid

Plant Controller

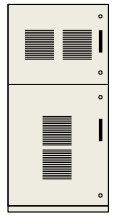
Gamesa Electric Orchestra

Gamesa Electric Proteus

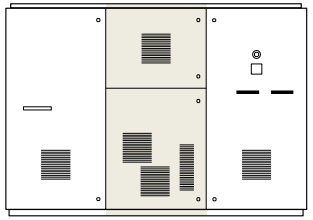
GamesaElectric Shaping new energy

The smart evolution of Utility-Scale Inverters

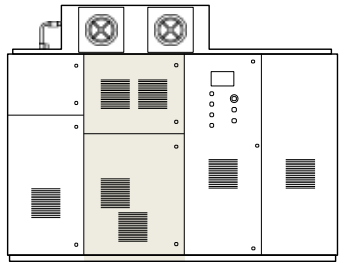
G10X Wind Converter



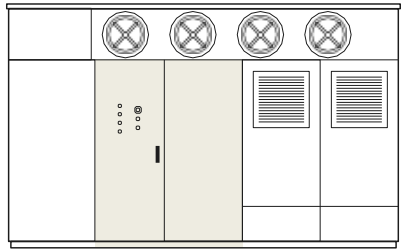
Gamesa Electric PV 1X series

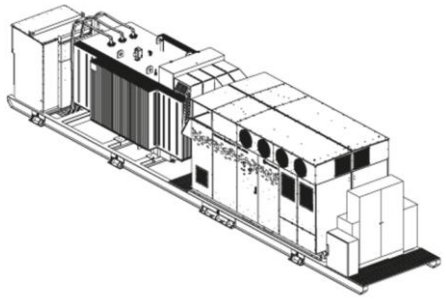


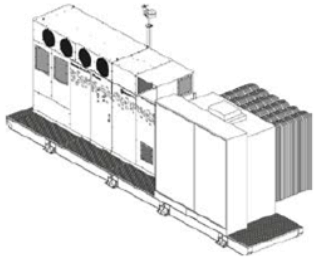
Gamesa Electric PV 2X series



Gamesa Electric PV 3X series







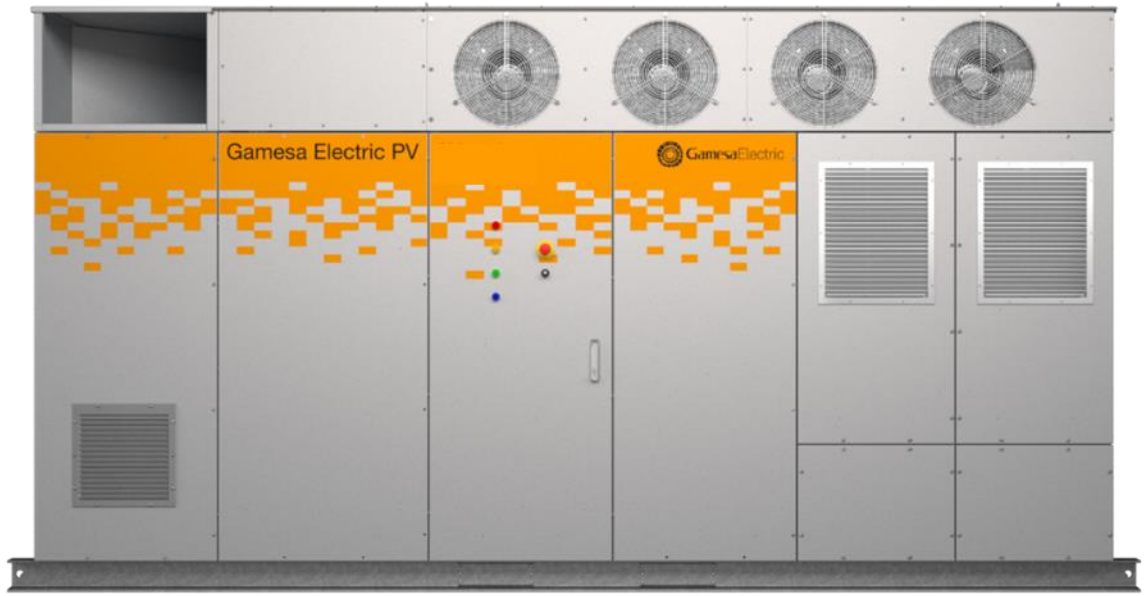
HIGHEST POWER DENSITY

HIGHEST EFFICIENCY

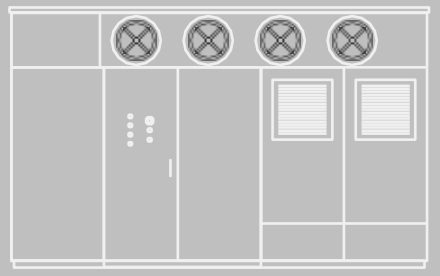
HIGHEST T RANGE

LONG LIFESPAN

9.4 MVA STATIONS



Lowering LCoE
from the
Inverter Perspective



GamesaElectric Shaping new energy

7 proven ways to improve LCoE in PV and Storage

2 HIGHER EFFICIENCY	+	2 REDUCED LOSSES	+	3 ADJUSTED COSTS

Success Story

50 MWp PV in Spain

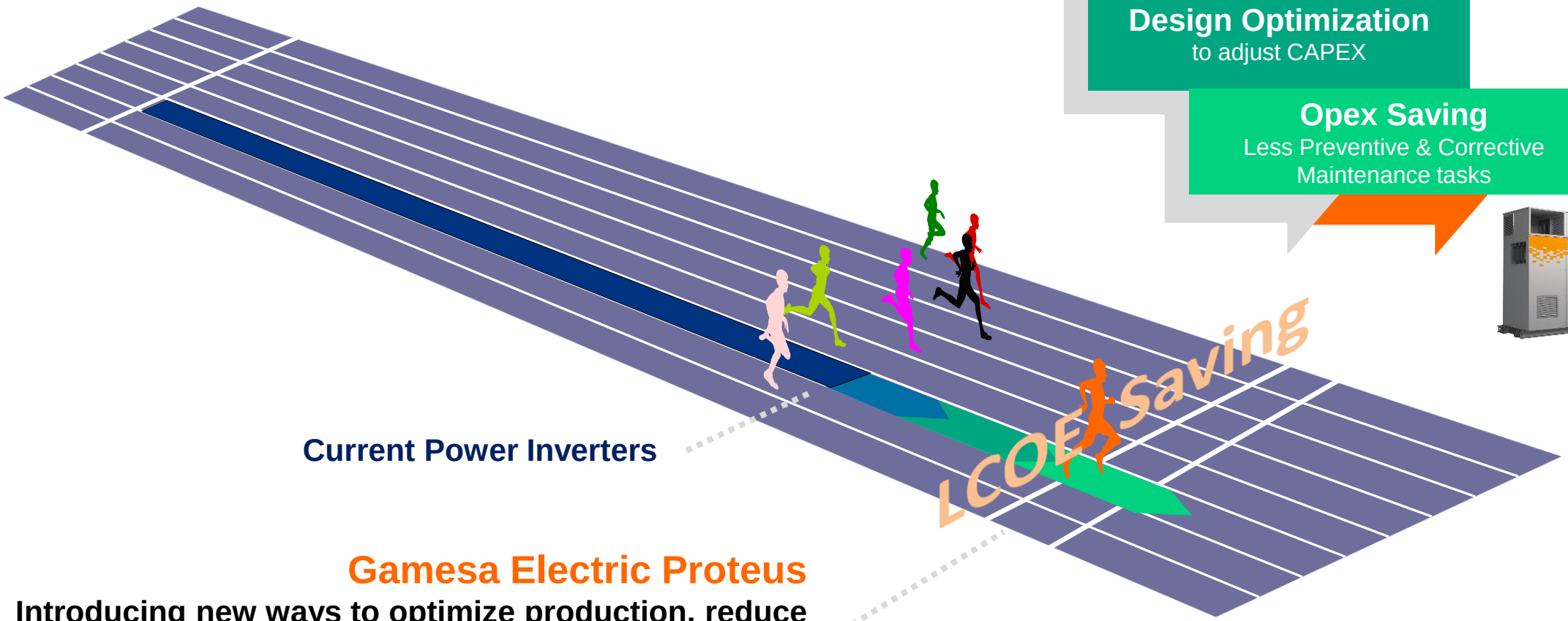
Lowering LCoE from the Inverter Perspective

$$LCOE = \frac{\text{Total Life Cycle Cost}}{\text{Total Lifetime Energy Production}}$$

Production
Efficiency plus Availability

Design Optimization
to adjust CAPEX

Opex Saving
Less Preventive & Corrective Maintenance tasks



Current Power Inverters

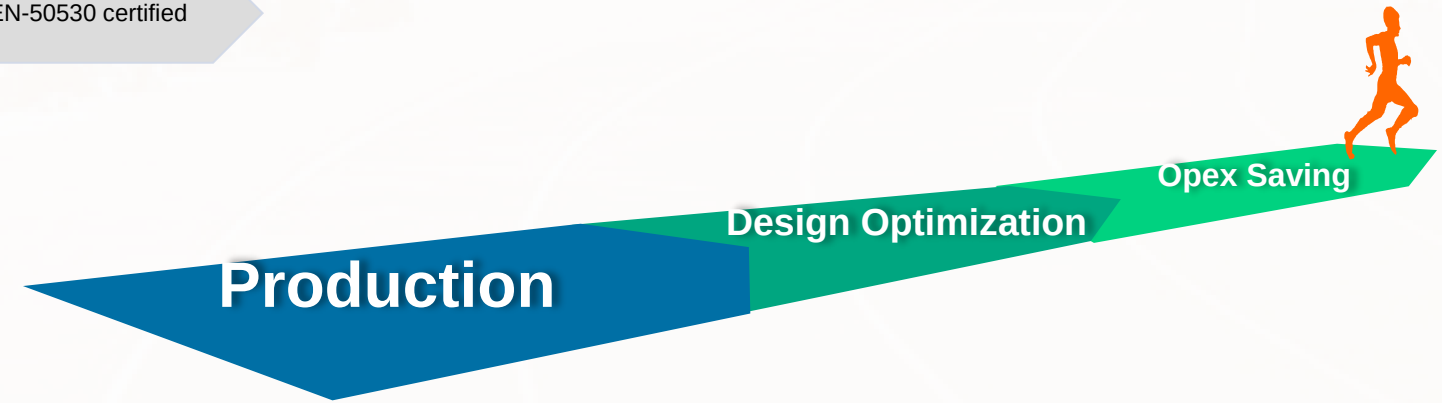
Gamesa Electric Proteus

Introducing new ways to optimize production, reduce maintenance and optimize PV& BESS Plant Designs

Lowering LCoE: Why us…. And How?

$$LCoE = \frac{\text{Total Life Cycle Cost}}{\text{Total Lifetime Energy Production}}$$

Lowest THD	THD 50th < 0.7% THD 2500th < 1%	IEEE-519 and IEC-617272 certified
Highest Efficiency	99.45%	IEC-61683 certified
Highest MPPT Efficiency	η_{STATIC} = 100% $\eta_{DYNAMIC}$ = 99.9%**	EN-50530 certified
Highest power density	PV → Up to 4.7 MVA PVS → Up to 9.4 MVA	
Lowest derating in Temperature	100% - 40ºC 89 % - 55ºC	
100% Performance	Using clipping energy to feed auxiliaries	



proven w
improve
in PV and
Storage

1

Focus decisions on obtaining max production

Ultra-High Efficiency and MPPT Efficiency

2

3

4

5

6

7

HIGHER EFFICIENCY

REDUCED LOSSES

ADJUSTED COSTS

Success Story:

50 MWp PV in Spain

1 - Focus decisions on obtaining maximum production

Ultra-High Efficiency and MPPT Efficiency

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Ultra-High Efficiency

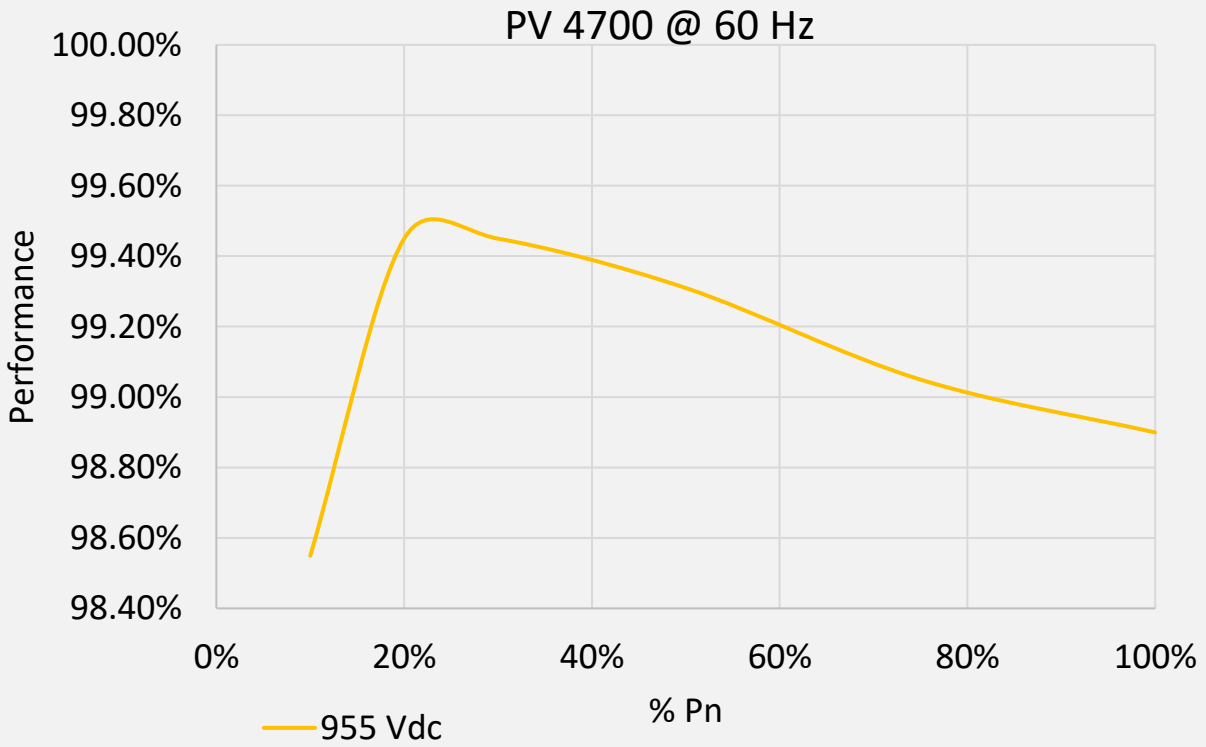
Proteus Peak efficiency is **99,45%**, and it's almost ever above 99% even if weighted values are considered (IEC 61683 certified).

Thanks to:

- Cooling system
- Highly-refined hardware design
- Control algorithms

More Instant Production -> Reduced LCoE

PROTEUS PV4700			
Frequency (Hz)	European efficiency	Californian efficiency	Maximum efficiency
50	99.17%	99.15%	99.34%
60	99.24%	99.24%	99.45%



1 - Focus decisions on obtaining maximum production

Ultra-High Efficiency and MPPT Efficiency

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MPPT Efficiency

Proteus PV family has the highest MPPT efficiency in the market

- Static efficiency > 0.5%
- Dynamic efficiency > 0.75%
- Applies to Power Yields

Fast and accurate solar radiation tracking -> Reduced LCoE

Ramp	η	Proteus PV	Inv 1	Inv 2
10% - 50%	Min	99.85%	98.02%	99.32%
	Overall	99.97%	99.21%	99.60%
	Max	99.99%	99.67%	99.82%
30% - 100%	Min	99.98%	99.05%	99.35%
	Overall	99.99%	99.43%	99.46%
	Max	100.00%	99.88%	99.61%

proven ways to improve in s

2

1. **Focus decisions on obtaining max production**
   Ultra-High Efficiency and MPPT Efficiency
2. **Maximize every opportunity to produce.**
   MPPT Extended Range
3.
4.
5.
6.
7.

HIGHER EFFICIENCY

REDUCED LOSSES

ADJUSTED COSTS

Success Story:
50 MWp PV in Spain

2 - Maximize every opportunity to produce

MPPT Extended Range 2%

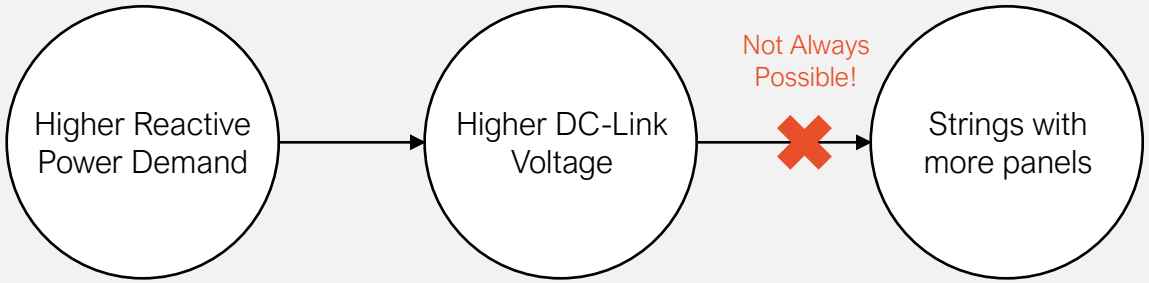
Shaping new energy

Evolution in Reactive Power affects to DC Voltage

Extended MPPT Range → Not limited to $V_{DC-Link} \geq \sqrt{2}V_{AC}$

- No DC-DC stage→ Less components, more reliable, higher efficiency
- Harmonic distortion below international standards (IEEE519)

Increase power yields, more flexible design -> reduce LCoE



AC Voltage	Standard MPPT	Extended MPPT	Extra Performance
690	976	955	2%
660	933	915	2%
630	891	875	2%
600	849	835	2%

proven ways to improve LCoE in

3

1. **Focus decisions on obtaining max production**
   Ultra-High Efficiency and MPPT Efficiency
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3. **Power Quality… is also money.**
   HF THDi
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HIGHER EFFICIENCY

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Success Story:
50 MWp PV in Spain

3 – Power Quality… is also money

THDi Energy losses must be considered in all Frequency Range

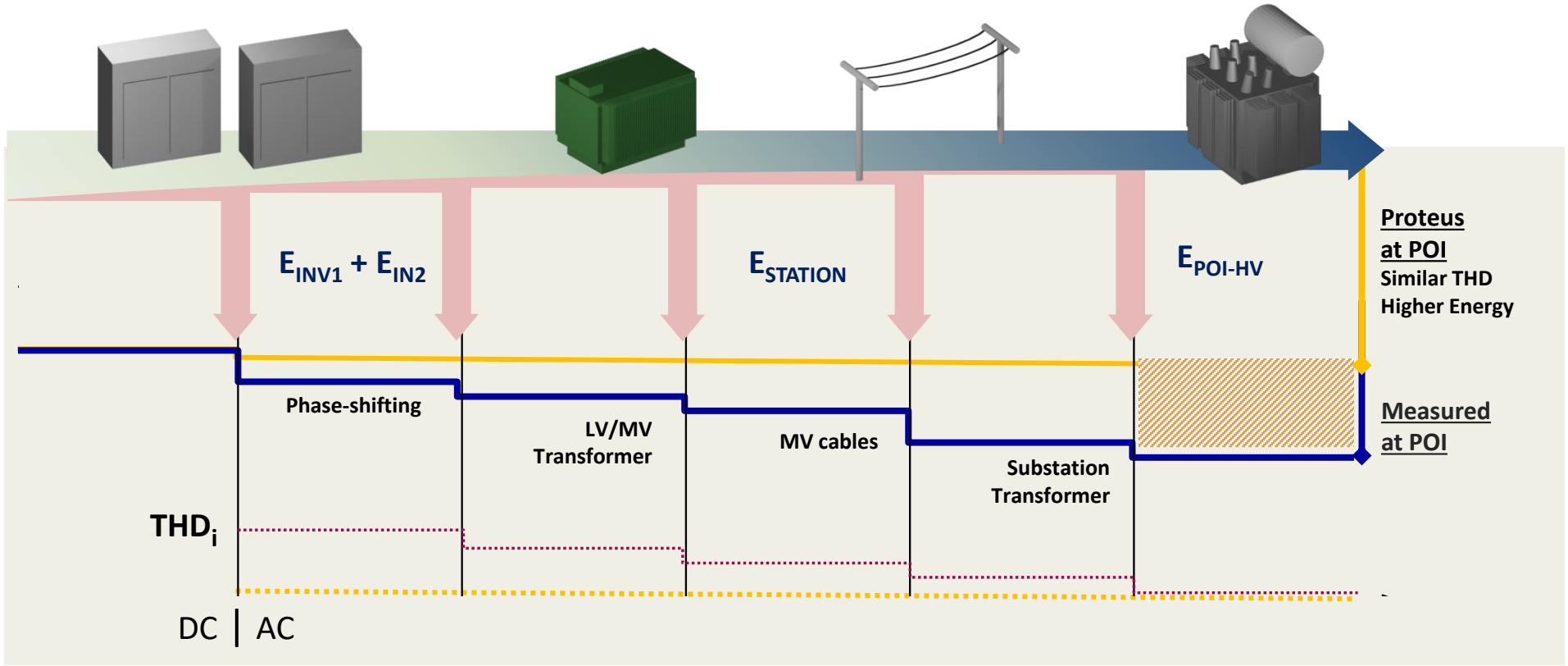
Inverters Switching frequency

- Above 50th harmonic, not included in certificates
- Higher impact in harmonic losses
- It is partially mitigated by Phase-Shifting

PV plant behaves like Low Pass Filter

- Meters measured any current
- High frequency currents filtered by PV plant
- Transformers and cables heating

Embedded HF filter in Proteus PV & PCS



— Inverter
THDi (50^{th})<3% ; THDi (2500^{th})<10%

— Gamesa Electric Proteus
- THDi (50^{th})<0,8% ; THDi (2500^{th})<1%

3 – Power Quality… is also money

Lower THDi means… lower LCoE

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Proteus PV & PCS
THDi (50th order) 0.7%
THDi (2500th order) 1.0%

NO Energy Waste in 25 years

Case A: Central + HF
THDi (50th order) 2,3%
THDi (2500th order) 3,2%

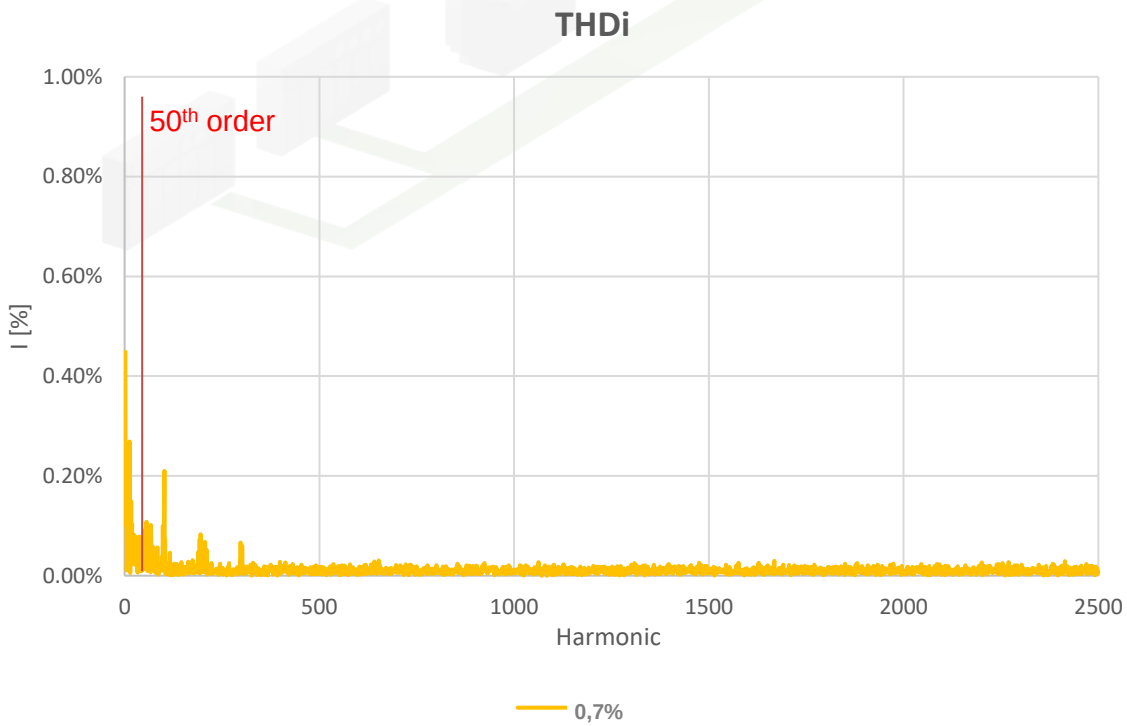
Year 0: -200 k€ // Year 25: -2,9 M€

Case String
THDi (50th order) 2,3%
THDi (2500th order) 10,3%

Year 0: -338 k€ // Year 25: -4,9 M€

- **Increased Grid stability**
- **More Revenues**
- **Reduces losses**
- **Avoid Transformer's breakdowns.**

-> Reduced LCoE



*235 MVA plant, energy price of 35 €/MWh and discount rate of 5% per year. The economic calculations only contemplate the pure ohmic losses, skin effect neither the impact on transformers nor capacitors are considered.

proven ways to improve LCoE in PV and Storage

4

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4. **Smarter if adaptable to instant conditions.**
   100% Performance
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HIGHER EFFICIENCY

REDUCED LOSSES

ADJUSTED COSTS

Success Story:
50 MWp PV in Spain

4 - Smarter if adaptable to instant conditions

100% Performance

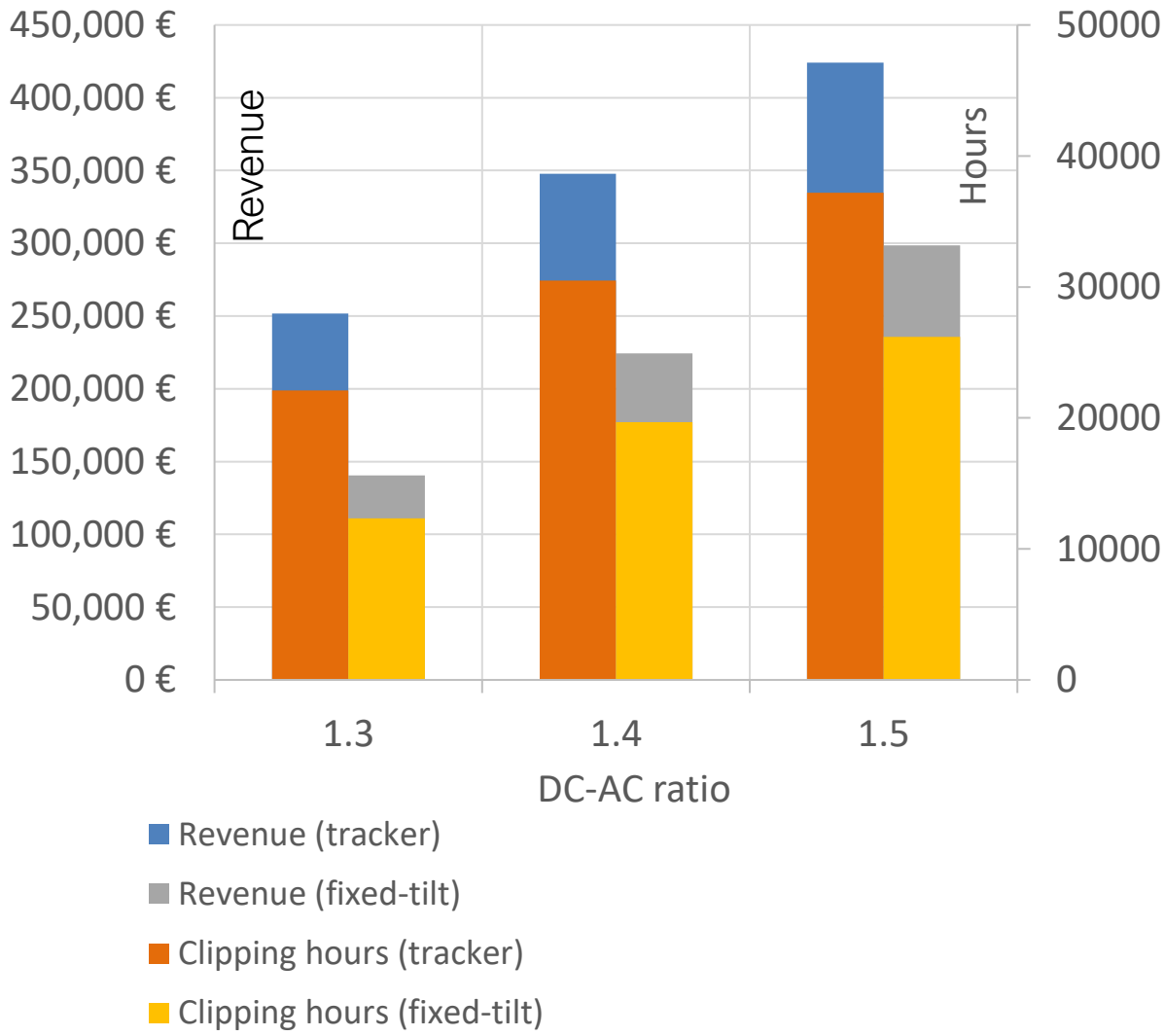
Proteus PV inverters are designed to compensate inverter losses for clipping without affecting to nominal inverter power

Proteus PV could harvest its own losses from the clipped energy

100% Performance: The equivalent performance ratio is increased to 100%

Extra energy production -> Reduced LCoE

Case: Antofagasta (Chile) - Revenue variation with DC-AC ratio



5 proven ways to improve LCoE in PV and Storage

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   100% Performance
5. **Bigger… is better.**
   Power Density to save costs and CO2 emmisions
6.
7.

HIGHER EFFICIENCY

REDUCED LOSSES

ADJUSTED COSTS

Success Story:
50 MWp PV in Spain

5 – Bigger… is better

Advantages of Power Density for saving costs and CO2

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2018

PV Panels Evolution

2022

91% higher power in 50% larger surface

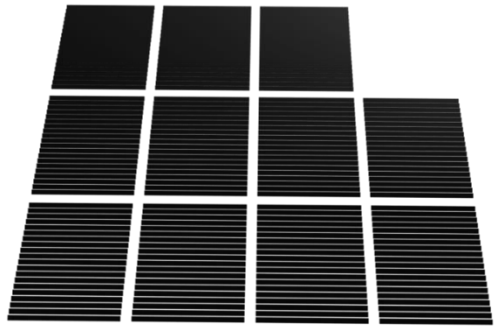
PV Panel from 350Wp to 670 Wp

PV String from 10 kW to 18,8 kW

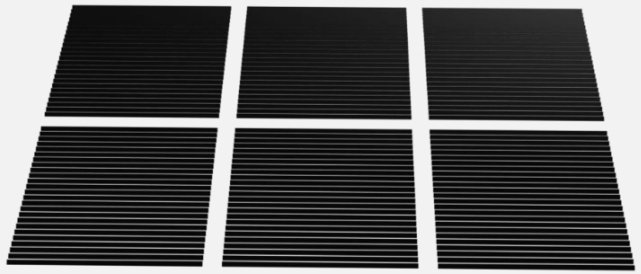
- Bigger Area per string
- Less String combiners
- Less DC wires
- Less trackers

EPC Comparison: 55 MW_{ac} Plant

Using 11 x 5 MVA LV/MV Stations



Gamesa Electric Proteus PV Stations: 6 x 9 MVA



- Less land
- Less roads
- Less Inverter foundations
- Less and shorter HV cabling
- Less substation feeders
- Less connections

-> Reduced LCoE

5 – Bigger… is better

Positive Impacts for LCOE and Environment

Proteus PV Stations	Market
0,34 W/Kg	0,24 W/Kg

Proteus PV Stations	Market
316 W/m2	235 W/m2

Proteus PV Stations	Market
1x 40ft	1.5 x 40ft

Simple, less units per project and less CO2 emissions -> Reduced LCoE

Evaluation done in Q1 2022 comparing *Gamesa Electric Proteus PV Station 9400* with 10 largest Utility Inverter Stations from 7 top-ten central inverter brands.

proven ways to improve LCoE in PV and Storage

6

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6. **Thermal Regulation is the key.**
   Coolbrid Cooling System
7.

HIGHER EFFICIENCY

REDUCED LOSSES

ADJUSTED COSTS

Success Story:
50 MWp PV in Spain

6 - Thermal Regulation is the key

Coolbrid: The key to achieve top performance in Efficiency and Durability

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CoolBrid; hybrid system with forced-aid + liquid:
Liquid cooling in inverter bridge and grid filter
Forced-air in small switches, electronics, fuses…

Perfect inner temperature regulation

Best performance in extreme conditions:
- Up to 4.7 MVA per unit (UEP)

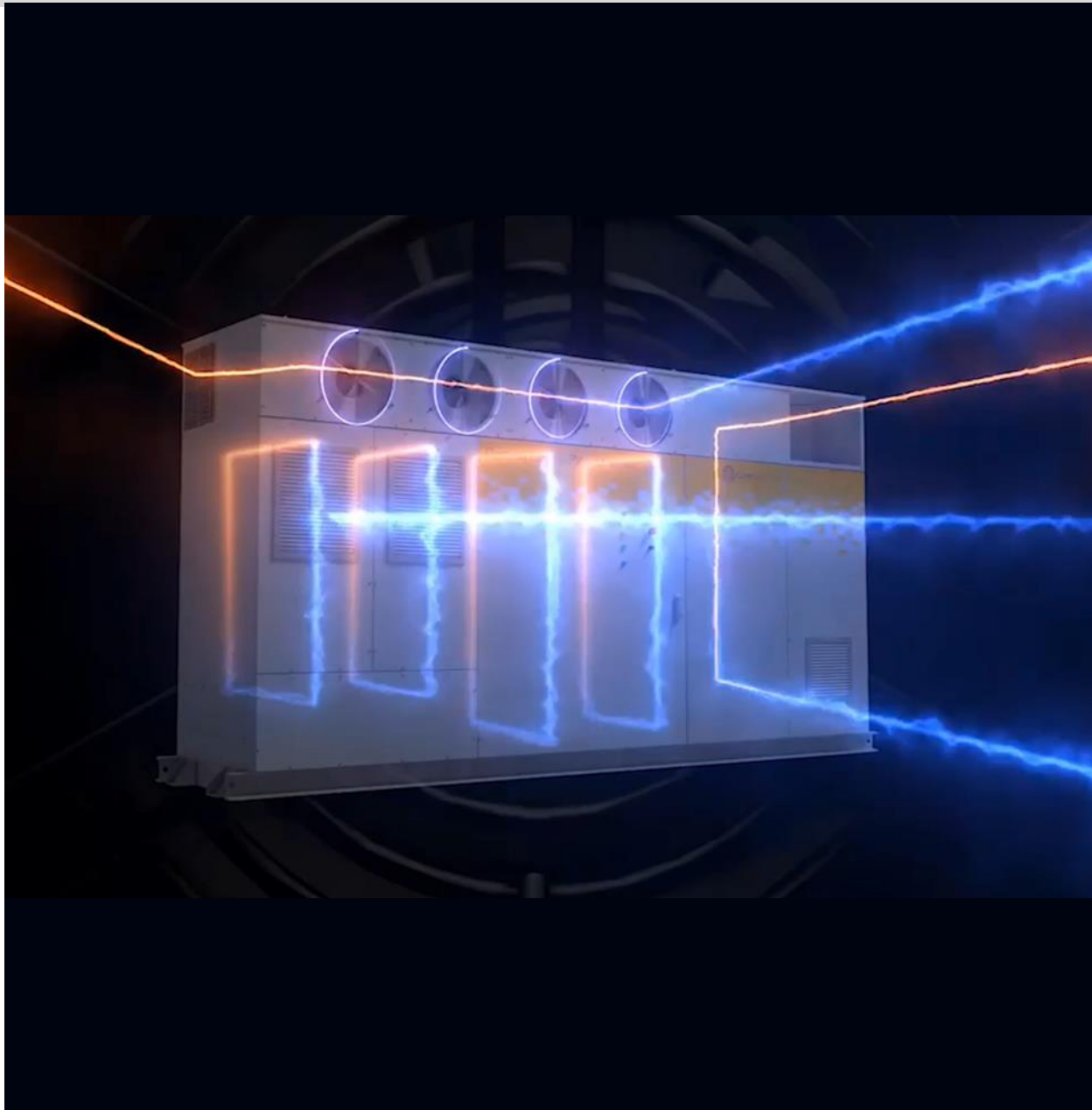
Low maintenance

Compact solution; space and weight saving

Extended lifetime and high MTBF:
- Components work far from its maximum capabilities

Reliability:
- More than 18 years of experience manufacturing liquid-cooled converters for wind turbines

Less Maintenance, more production -> Reduced LCoE



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7. **Limits are there… but to be overcome.**
   More than 30 years lifetime with just preventive maintenance

HIGHER EFFICIENCY

REDUCED LOSSES

ADJUSTED COSTS

Success Story:
50 MWp PV in Spain

7 – Limits are there… but to be overcome

More than 30 years lifetime with just preventive maintenance…

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Reduction of costs in replacement

- Critical components achieve 30 years of lifetime
- Main components account for 70% of PV inverter cost.
- Components operating far below their thermal limits.
- No inverter replacement during project lifecycle:
  - Reduced costs
  - Reduced risks

-> Reduced LCoE

“Inverter Replacement currently represents 25% of O&M Costs”

North America Solar PV Capital and OPEX Cost 2022 – IHS Markit

Proteus PV Critical Component	Load	Lifetime years
Busbars	80%	-
DC Disconnector	77%	>40
DC Bus Capacitors	65%	>40
IGBT	96%	> 50
AC Inductance	99%	>50
AC Breaker	98%	>50
AC Filter Capacitors	75%	>30
CCU	-	>40

Working conditions

Full Power @ 55ºC 12 hours / day
Reactive power 12 hours / night
Lifetime calculation limited by supplier curves.

GamesaElectric | Shaping new energy

proven ways to improve LCoE in PV and Storage

1	**Focus decisions on obtaining max production** Ultra-High Efficiency and MPPT Efficiency	HIGHER EFFICIENCY
2	**Maximize every opportunity to produce.** MPPT Extended Range	
3	**Power Quality… is also money.** HF THDi	REDUCED LOSSES
4	**Smarter if adaptable to instant conditions.** 100% Performance	
5	**Bigger… is better.** Power Density to save costs and CO2 emmisions	ADJUSTED COSTS
6	**Thermal Regulation is the key.** Coolbrid Cooling System	
7	**Limits are there… but to be overcome.** More than 30 years lifetime with just preventive maintenance	

Success Story:
50 MWp PV in Spain

Success Story: 50 MWp in Spain

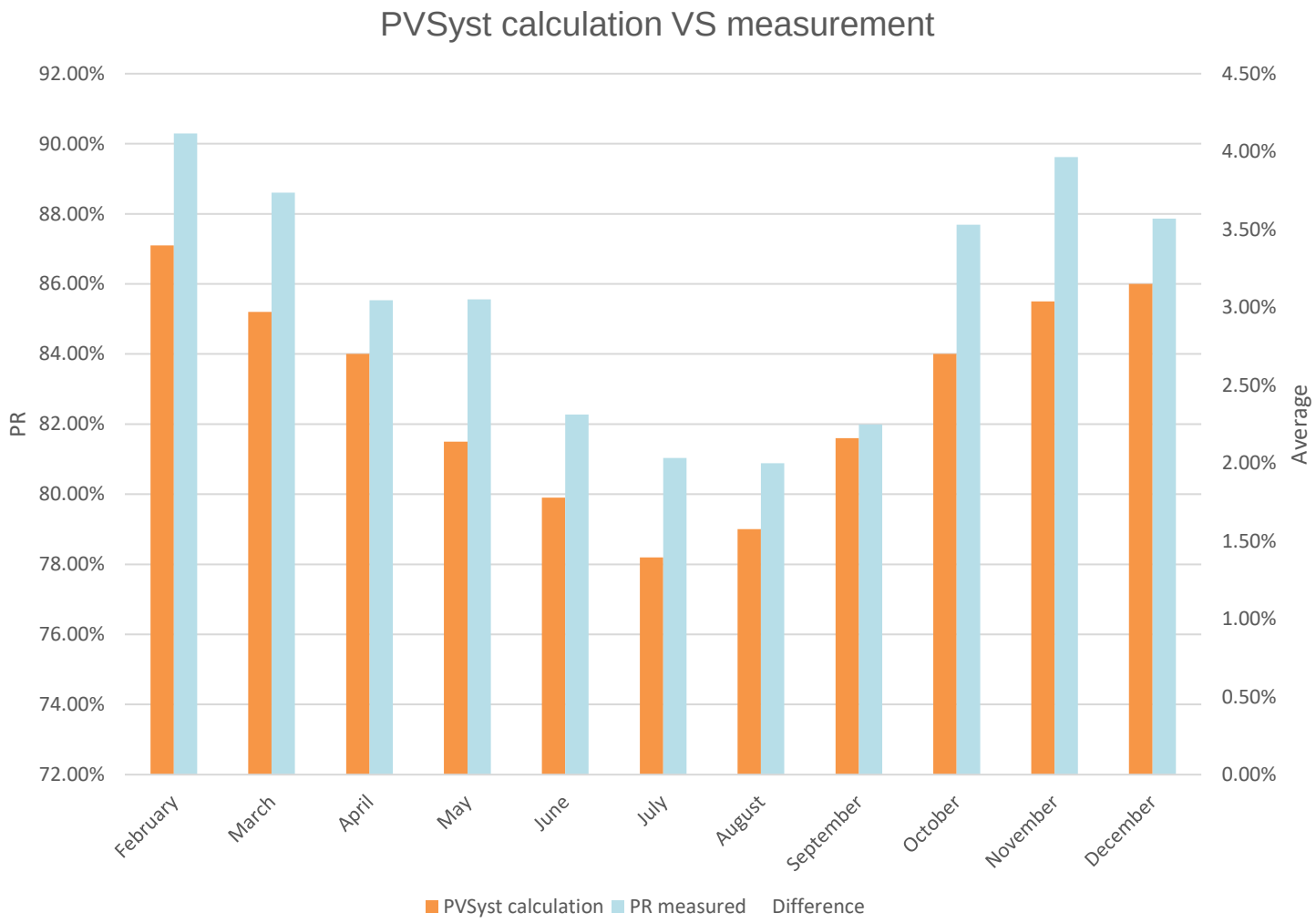
Improvement of PR above 2,6%

GamesaElectric Shaping new energy

50 MWp PV plant in Spain - 2021

- Location: Andalucia (Spain)
- Temperatures: -10ºC / 45ºC
- Nominal power: 50MWp
- Equipment: 13 x Gamesa Electric PV Inverters in 7 Stations
- Ratio DC/AC: 1,06
- Commissioning date: 2020
- Comparison of the PR calculated by PVSyst in the initial phase of the project with the PR measured in 2021

- **Average annual improvement: 2.67%**
- **Availability in Year 2021 > 99,5 %**



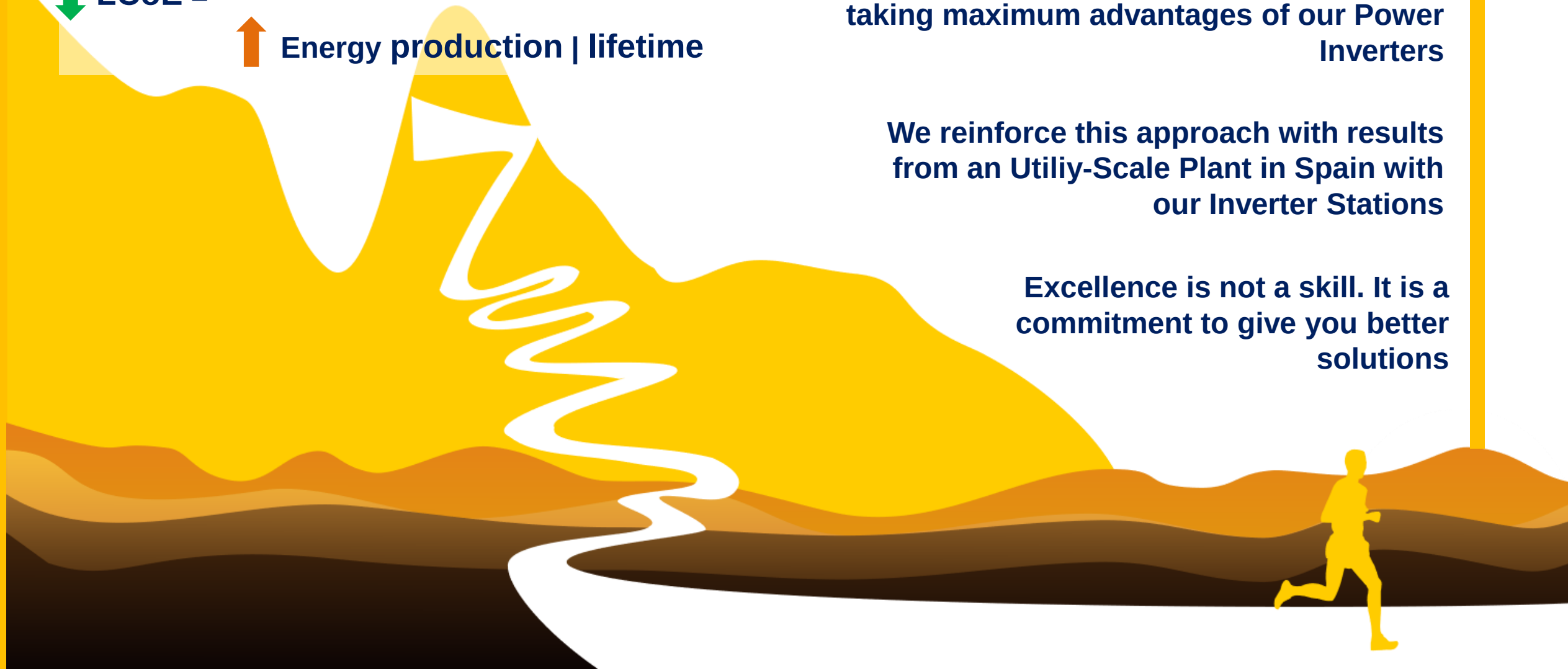
The Bottom Line…

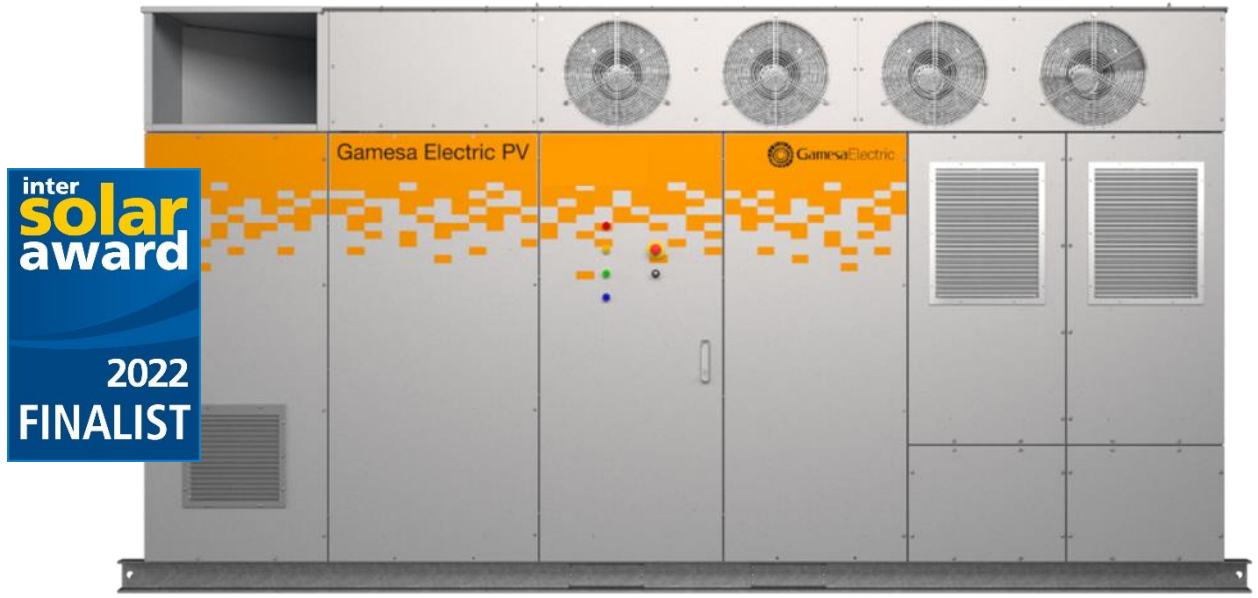
$$\downarrow \text{LCoE} = \frac{\downarrow \text{CapEx} + \downarrow \text{OpEx} \mid \text{lifetime}}{\uparrow \text{Energy production} \mid \text{lifetime}}$$

We have shown some ways to reduce LCoE taking maximum advantages of our Power Inverters

We reinforce this approach with results from an Utiliy-Scale Plant in Spain with our Inverter Stations

Excellence is not a skill. It is a commitment to give you better solutions





Contact for more info

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