EUREM
European EnergyManager

10th International Conference for European Energy Managers
30th September / 1st October 2020, Athens, Greece

Operational Commissioning of Photovoltaic systems

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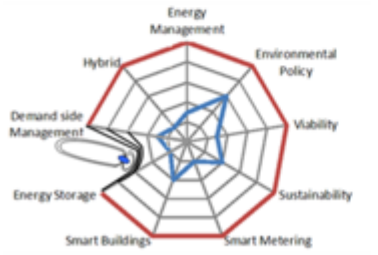

Adamsnet - Hydra

KYANIDIS ENERGY

IDS
INDUSTRIAL DRONE SERVICES

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History of Constructors vs Quality

Energy inspector

Renewable Energy inspector

ISO 50001

Energy manager

EN 62446

PV installation commissioning

BASIC TOPICS OF PV INVESTMENT STABILITY

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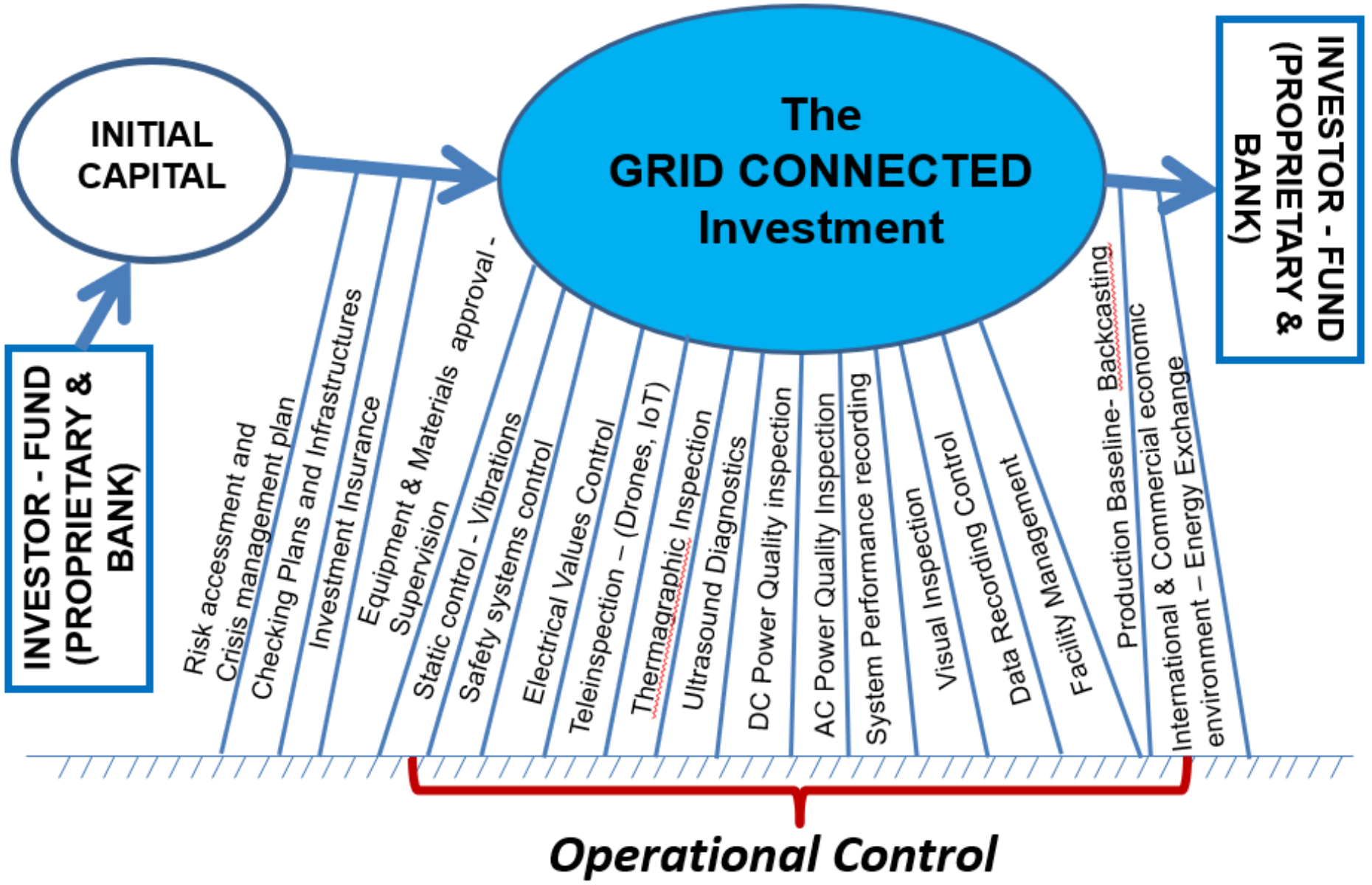

The Warranty of Investment depends on the Operational Inspection

SUNSTAINABILITY AND OPERATIONAL PERFORMANCE OF PV Systems

- Economic values control
- Design and system structure checking
- Static – Dynamic control
- Insurance option
- Construction Supervision
- Operational control and audits (Diagnostic measurements and approvals)
- Performance approval
- Uninterruptible and Systematic recording and data analysis
- Facility management Team
- International and Commercial economic environment – Energy Exchange Market

CERTIFICATION

INVESTOR

CAPITAL

INVESTMENT

=

SUSTAINABILITY PROFIT

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H Kyanidis Energy LEAD THE MARKET

- Strict adherence to updated standards with emphasis on investment sustainability

- Enrich the template with mixture of measurements, risk assessment, the terms of the contract with DNO, and the experience of the installation methods and the commercial reality

- The Operational COMMISSIONING includes also corrective actions to be taken by the manufacturer and the facility management team

- Quality is finally the warranty of the investment

ENRICHED STANDARD WITH SPECIFIC APPLICATIONS IN ORDER TO CERTIFY THE PV INSTALLATION AND ALSO THE INVESTOR BENEFITS

IEC 60050-131, *International Electrotechnical Vocabulary – Part 131: Circuit theory*

IEC 60216-2, *Electrical insulating materials – Thermal endurance properties – Part 2: Determination of thermal endurance properties of electrical insulating materials – Choice of test criteria*

IEC 60216-5, *Electrical insulating materials – Thermal endurance properties – Part 5: Determination of relative thermal endurance index (RTE) of an insulating material*

IEC 60269-1, *Low-voltage fuses – Part 1: General requirements*

IEC 61095, *Electromechanical contactors for household and similar purposes*

IEC 61215-1, *Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 1: Test requirements*

IEC 61439-1, *Low-voltage switchgear and controlgear assemblies – Part 1: General rules*

IEC 61724-1, *Photovoltaic system performance – Part 1: Monitoring*

IEC 61730-1, *Photovoltaic (PV) module safety qualification –Part 1: Requirements for construction*

IEC 61730-2, *Photovoltaic (PV) module safety qualification –Part 1: Requirements for testing*

IEC TS 61836, *Solar photovoltaic energy systems – Terms, definitions and symbols*

IEC 62109-1, *Safety of power converters for use in photovoltaic power systems – Part 1: General requirements*

IEC 62446-1, *Photovoltaic (PV) systems – Requirements for testing, documentation and maintenance – Part 1: Grid connected systems – Documentation, commissioning tests and inspection*

IEC (TS 62446-3 2017)

IEC 62446-2:–, *Photovoltaic (PV) systems – Requirements for testing, documentation and maintenance – Part 2: Grid connected photovoltaic (PV) systems – Maintenance of PV systems*[1]

IEC 62930:–, *Electric cables for photovoltaic systems with a voltage rating of 1,5 kV d.c.*[1]

ISO 9488, *Solar energy – Vocabulary*

ISO 9712, *Non-destructive testing — Qualification and certification of NDT Personnel*

VATh- Directive, *Electrical Infrared Inspections – Low Voltage. Planning, execution and documentation of infrared surveys on electrical systems and components ≤1kV* (http://www.vath.de/docs/richtlinien/VATh-Richtlinie_Elektro_NS+PV_engl_web.pdf)

EN 16714-3, *Non-destructive testing – Thermographic testing of electric installations*

EN 50110-1, *Operation of electrical installations – Part 1: General requirements*

DGUV BGV/GUV-V A3 E, *Accident prevention regulations, Electrical installations and equipment*

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Certifications

Dupline Fieldbus Installationbus

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FLUKE

Bicsi RCDD

GRUNDFOS

CARLO GAVAZZI

ue SYSTEMS INC The ultrasound approach

PANDUIT

ΥΠΟΥΡΓΕΙΟ ΠΕΡΙΒΑΛΛΟΝΤΟΣ ΕΝΕΡΓΕΙΑΣ & ΚΛΙΜΑΤΙΚΗΣ ΑΛΛΑΓΗΣ

infraspection institute

ΕΛΟΤ

PAE RAE ΡΥΘΜΙΣΤΙΚΗ ΑΡΧΗ ΕΝΕΡΓΕΙΑΣ REGULATORY AUTHORITY FOR ENERGY

OEB

KACO new energy.

cea CERTIFIED ENERGY AUDITOR

ΕΛΛΗΝΙΚΗ ΔΗΜΟΚΡΑΤΙΑ εκδδα ΕΘΝΙΚΟ ΚΕΝΤΡΟ ΔΗΜΟΣΙΑΣ ΔΙΟΙΚΗΣΗΣ & ΑΥΤΟΔΙΟΙΚΗΣΗΣ

CMVP®

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Drone Inspection of PV Systems

SERVICES

DETAILED REPROTING

PV system anomalies analysis with high quality visual and thermal cameras

DIGITAL GROUND MODELING

Digital modeling and volumetric measurements.

3D MODELING

3D Design

Thermal Orthomosaic

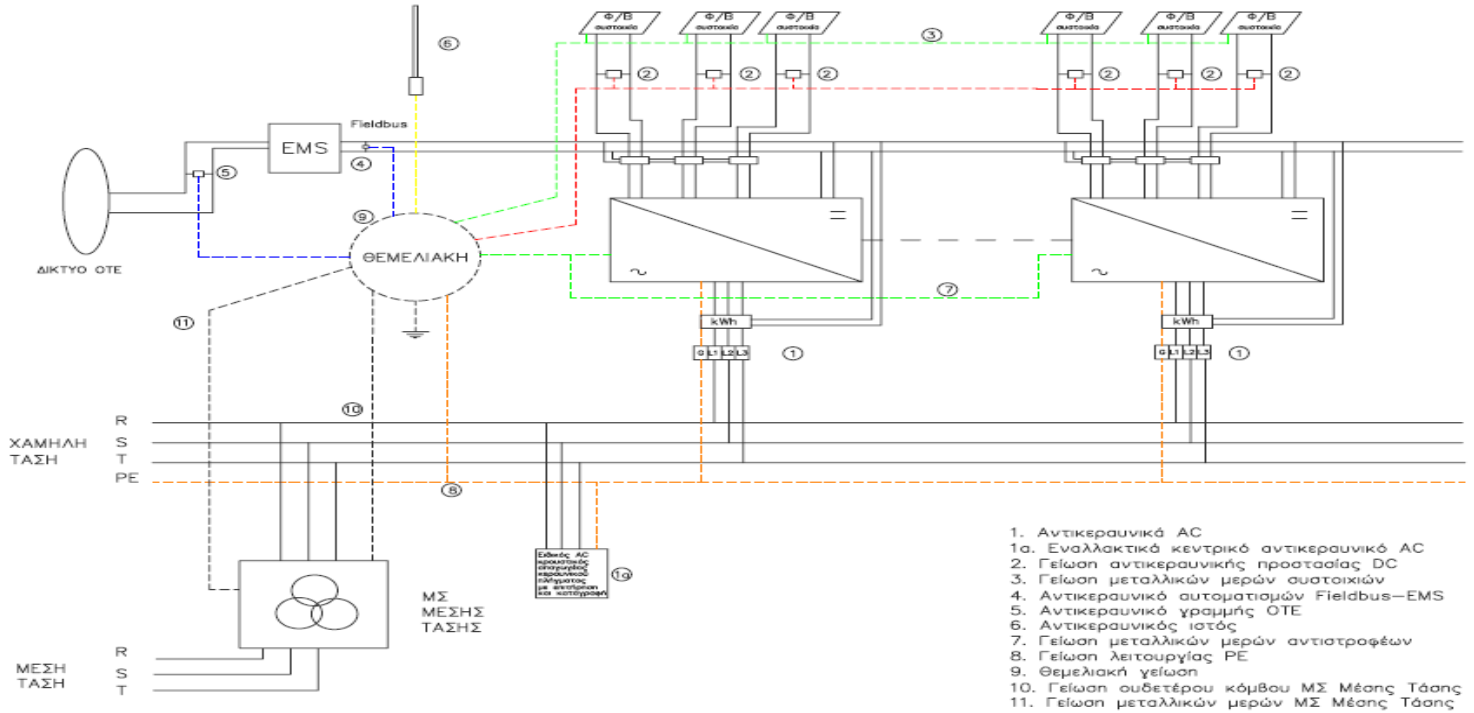
RGB Orthomosaic

High quality analysis of topographic measurements

PHOTOGRAPH AND VIDEO HD SERVICES

1. Visual Audits

- **Electrical Installation Connections**
- **Grounding and Bonding**
- **Lightning Protection**
- **PV Panels Static Structure Assessment**



Σημείωση: Το σχήμα περιλαμβάνει μόνο γειώσεις και διατάξεις προστασίας έναντι κεραυνικού πλήγματος. Η παράλειψη των λοιπών προστατευτικών διατάξεων έγινε για λόγους κατανόησης της αντικεραυνικής προστασίας. Στη συγκεκριμένη περίπτωση απαιτείται αντίσταση γείωσης <1ohm.

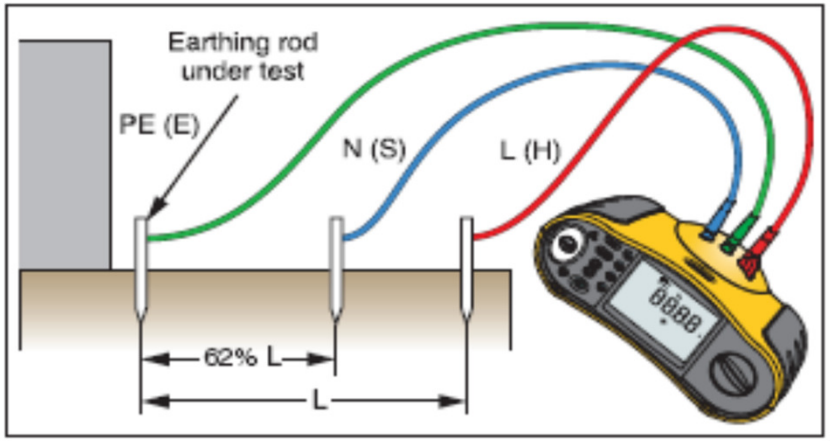
2. Electrical Measurements

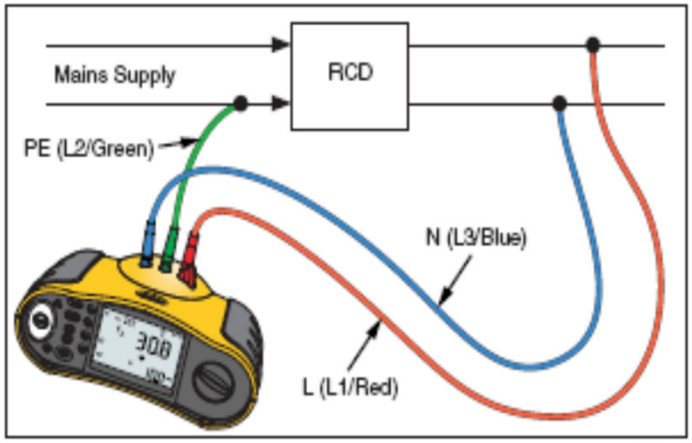
(Open Circuit)

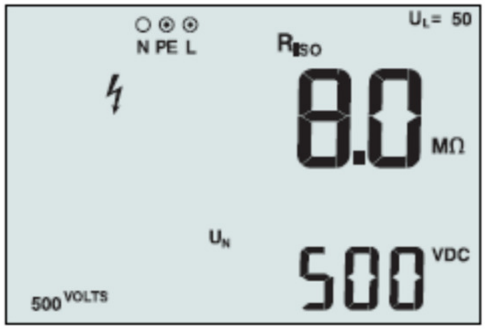
EN60364 – HD384

- Insulation resistance
- Loop resistance
- Line resistance
- Earth resistance
- Earth fault current
- RCD switching time and tripping level
- Trip time and current for RCD
- Voltage and Phase sequence measurements

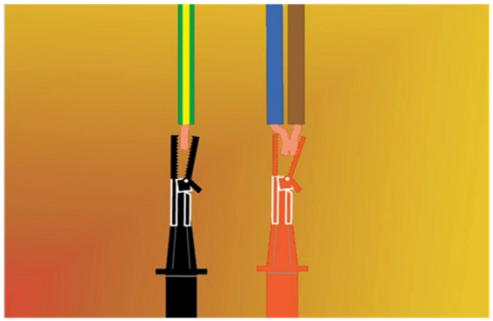
The above measurements and the Vibration test can be made during the construction phase of a project, as well as in the phase of the system operation commissioning process.

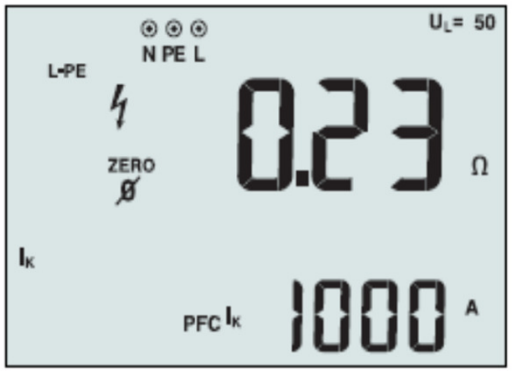

Earthing rod
under test
PE (E)
N (S)
L (H)
62% L
L


Mains Supply
RCD
PE (L2/Green)
N (L3/Blue)
L (L1/Red)

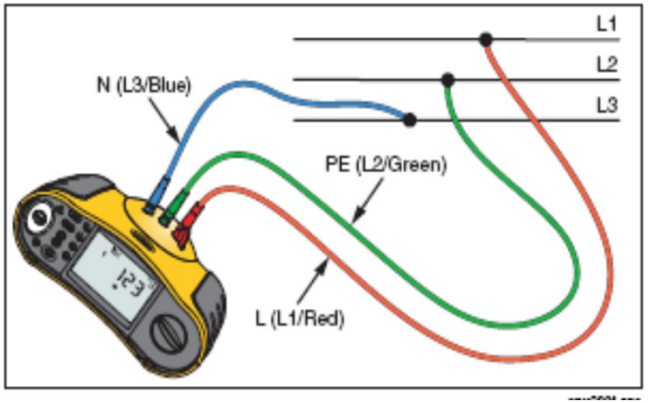

N PE L
R_{ISO}
U_L= 50
8.0
MΩ
U_N
500
VDC
500 VOLTS


R_{ISO}
N PE L



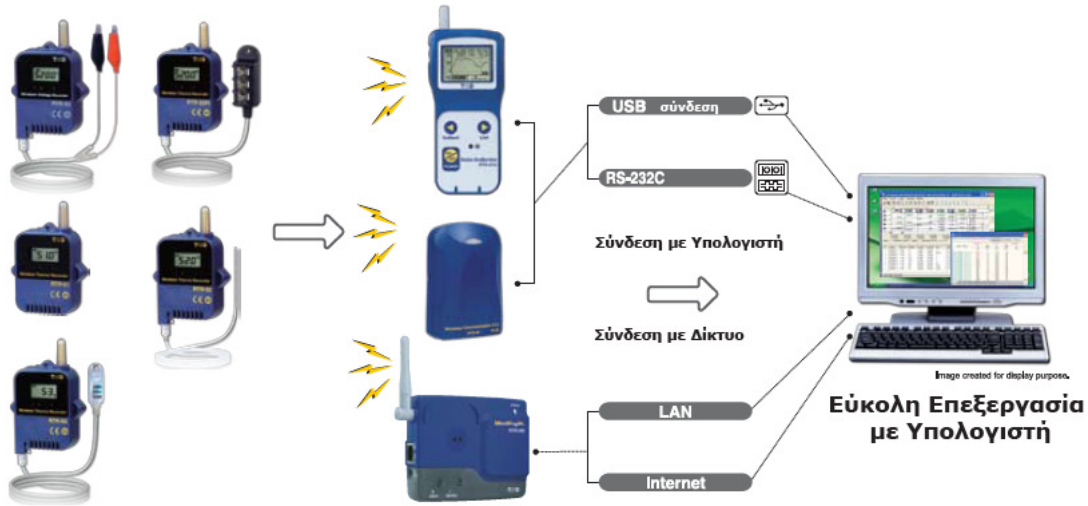

N PE L
U_L= 50
L-PE
ZERO
0.23
Ω
I_K
PFC I_K
1000
A


Z_I
N PE L

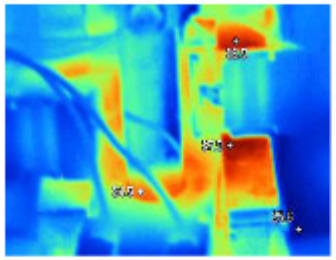

L1
L2
L3
N (L3/Blue)
PE (L2/Green)
L (L1/Red)

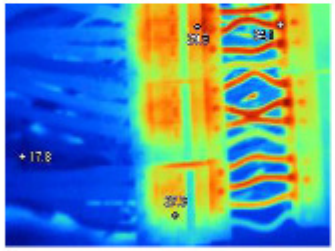
3. Environmental Conditions

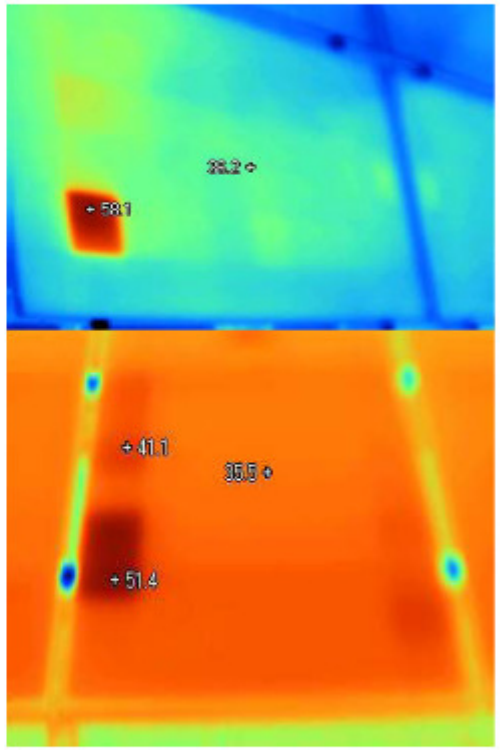
- **Time based** of **Temperatur**e and **Humidity** recording with Specific analog Loggers
- **Time based** of **Solar radiation** recording



4. Thermographic Inspection







Thermocamera FLUKE Ti 35

Hot-spot ΔT >>8°C

- Hot-spot in Electrical panel
- Hot-spot in Photovoltaic panel

Failures that prevent the project Insurance

INDUSTRIAL DRONE SERVICES

AERIAL PV INSPECTION

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APPLICATIONS

Specifications According **IEC (TS 62446-3)**

- Photo Analysis: 20MP
- Video Analysis: 4K, 30FPS
- Thermal Imager Analysis 640*512PX, 13mm, 30hz
- Zoom: 30X

PANEL INSPECTION ON SOLAR TRACKERS

Aerial inspection with thermal and RGB cameras has comparative advantages over ground inspection as it adapts to the angle variation of the system avoiding glare and reflections.

CONSTRUCTION MONITORING

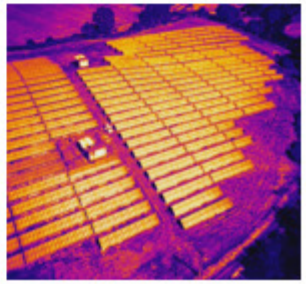
Monitor the maintenance and construction works of Solar Parks. Track the progress in different stages from start to completion of the project.

ROOFTOP PV PANEL INSPECTION

Thermal and optical inspection of solar modules installed on industrial and residential rooftops. Fast, efficient and safe panel inspection on rooftops with varying inclination and height.

UTILITY-SCALE SOLAR PANEL INSPECTION

Inspection of large-scale Solar Park installations with 100% coverage and detailed reporting.



5. DC values evaluation

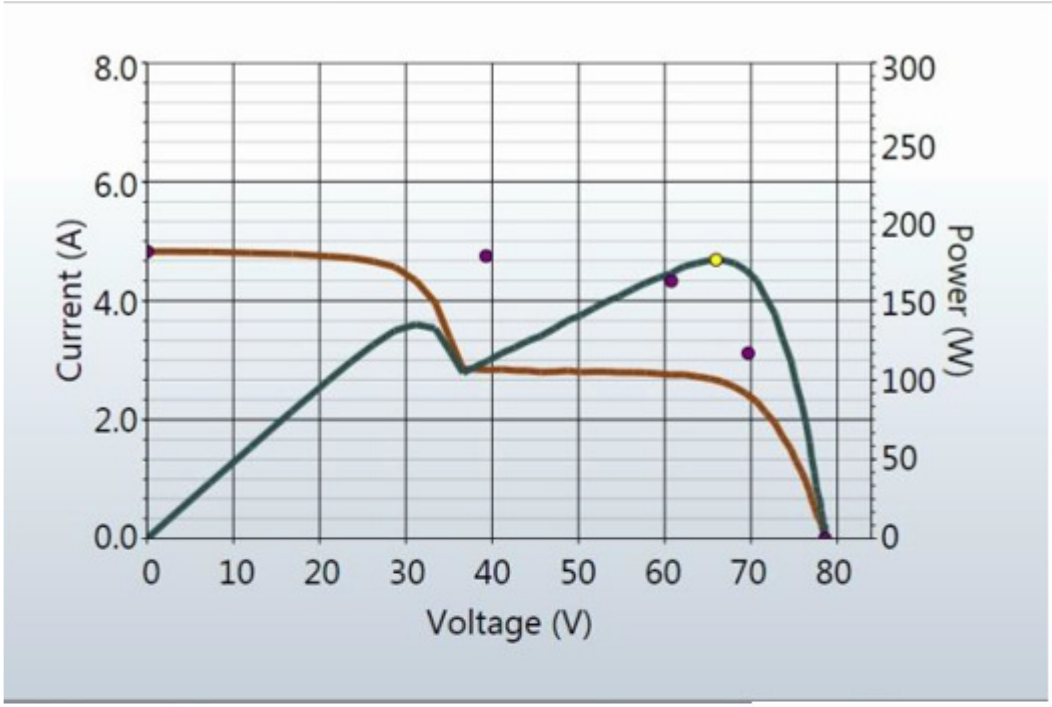
Fluke 289

HT I-V Curve Analyzer

Metrel MI 3108 EurotestPV

Fluke a3003 FC Wireless 2000 A DC Current Clamp Meter

- DC Voltage comparison with the expected
- DC Current comparison with the expected
- Curve I-V measurement



The effect of partial shading on 2 parallel strings with 8 PV-panels 175-watt

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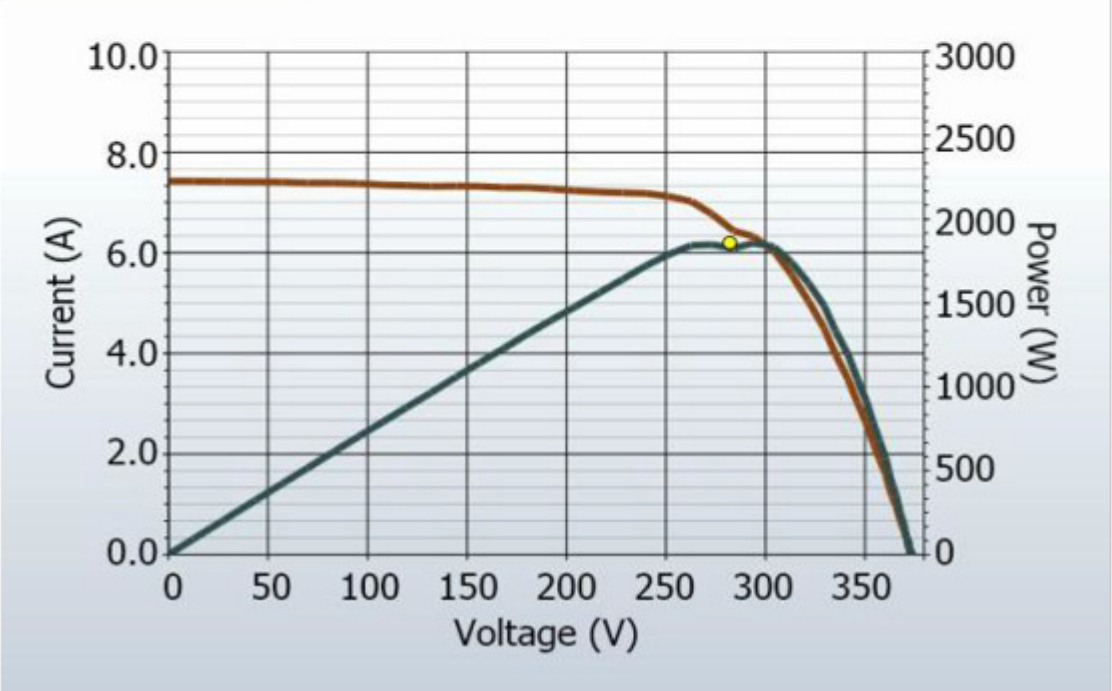
The effect of partial shading with a business card on a 15 PV-panels system (180-watt each)



6. AC Power Quality Evaluation

FLUKE 438 II
Power quality analyzer

Fluke 125 Industrial ScopeMeter

Fluke 369
Residual Current Meter

- Voltage & current – harmonic distortion measurements of the main and also the individual MCBs.
- EN 50160 standard compliance
- DC injection measurement which shall not exceed more than 0,5% of the nominal current output in a period with full production
- Earth leakage measures or records

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POWER QUALITY

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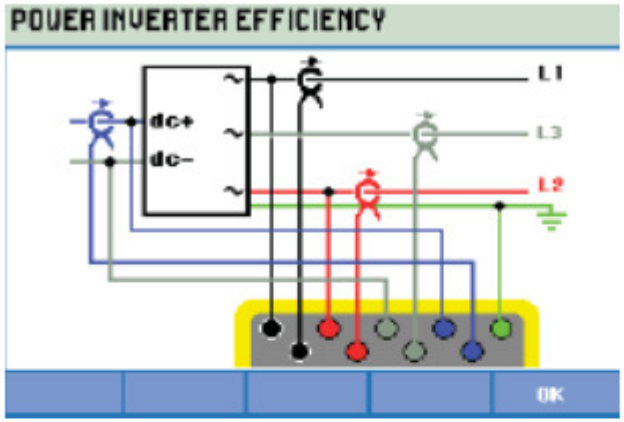
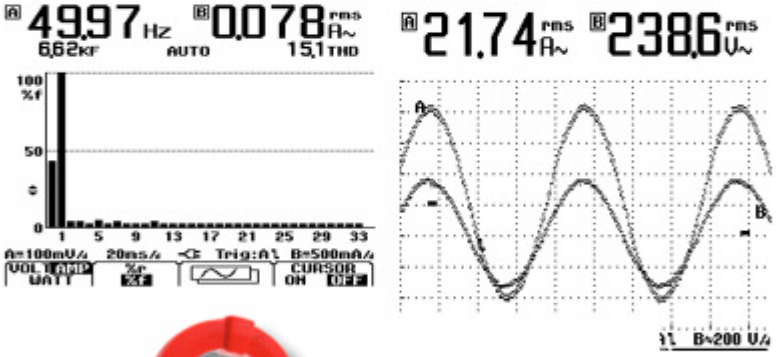
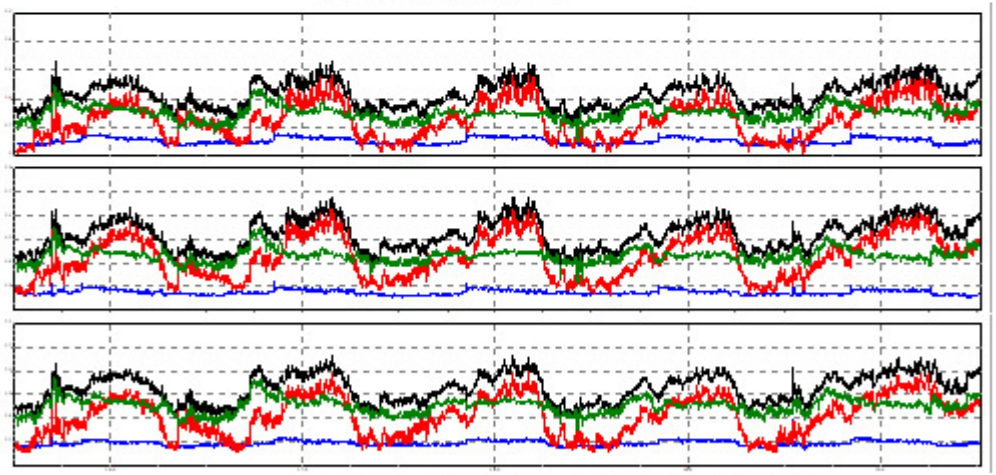
EN 50160

1	Volts and Amps	PASS
2	Frequency / Unbalance%	PASS
3	Unbalance volts&Amps	PASS
4	Flicker (short Long term flicker, Dc, Dmax, TD)	PASS
5	Harmonics voltage(THD , DC)	PASS
6	Harmonics amps(THD , DC)	FAIL
7	Power	PASS
8	Energy	PASS



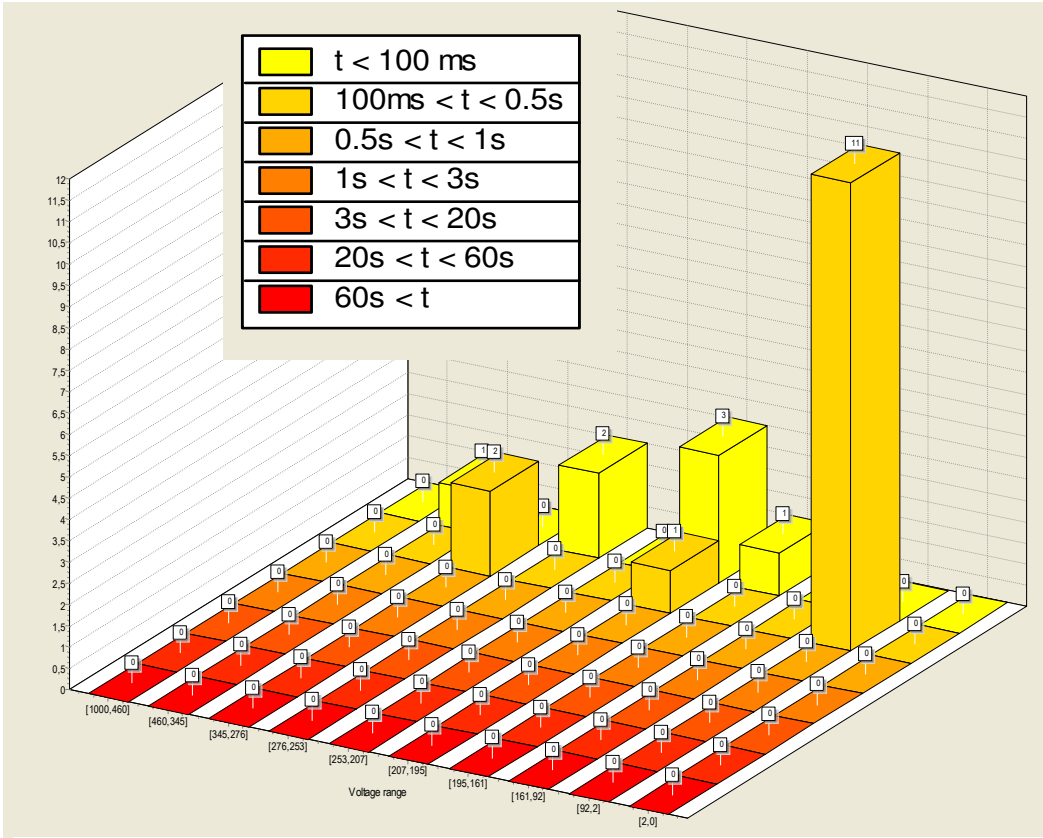
Power quality analyzer
FLUKE 438 II





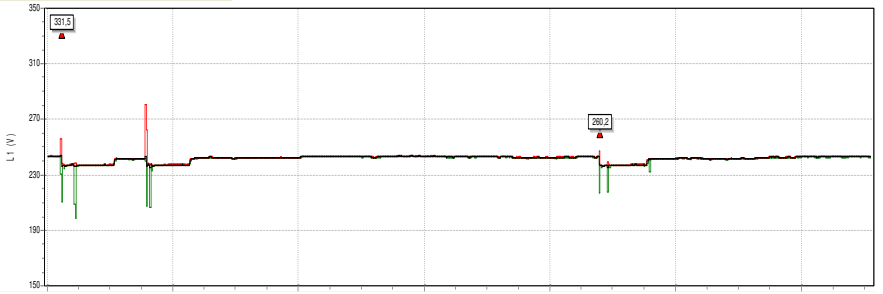
THDv, HDv3, HDv5, HDv7

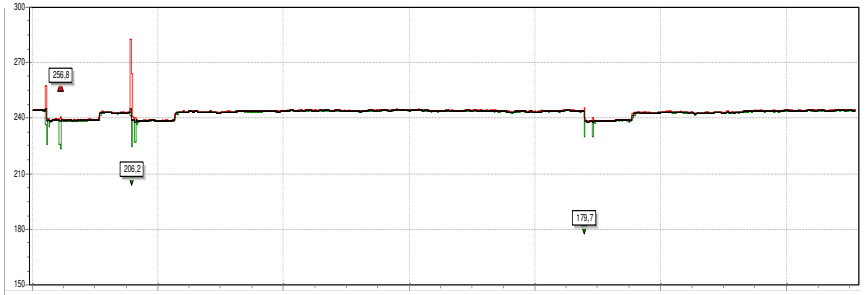
Earth leakage recording(με Fluke 369 FC)

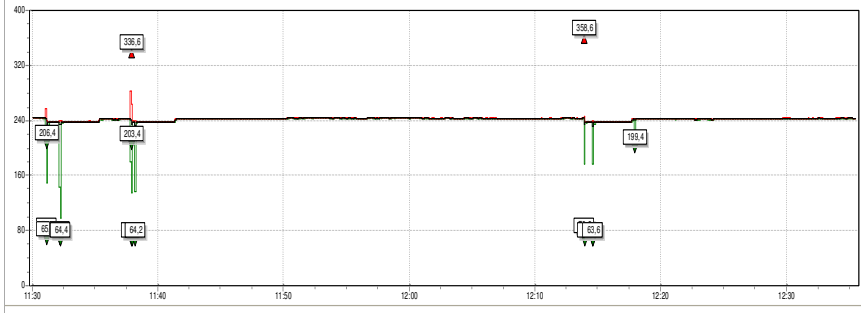


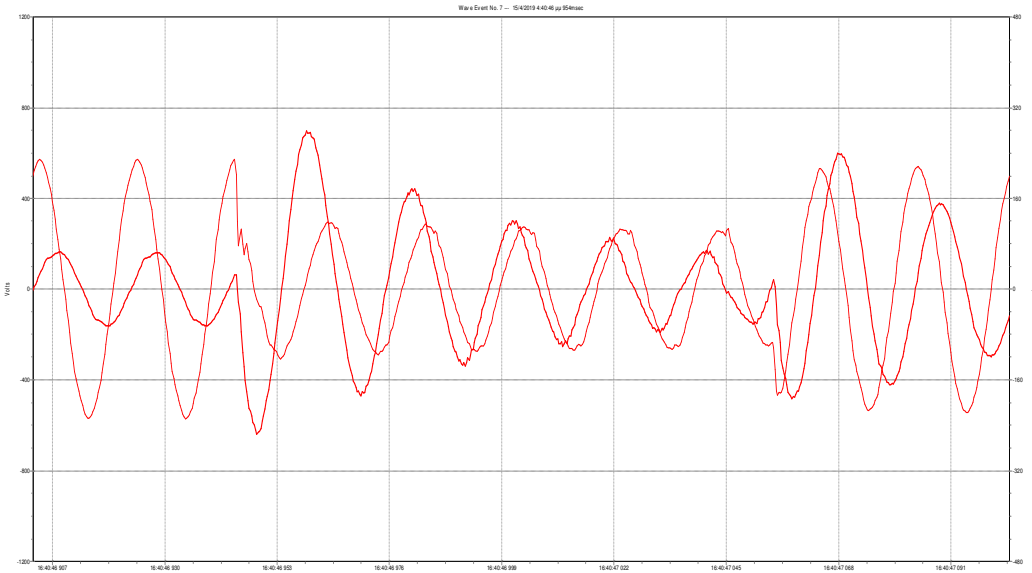
Swell voltage u[%]	Duration t[ms]				
	t < 10	10 <= t <= 500	500 < t <= 5000	5000 < t <= 60000	60000 < t
u >= 120	0	3	0	0	0
120 > u > 110	0	2	0	0	0

Residual voltage u[%]	Duration t[ms]					
	t < 10	10 <= t <= 200	200 < t <= 500	500 < t <= 1000	1000 < t <= 5000	5
90 > u >= 80	2	2	0	0	0	0
80 > u >= 70	0	1	0	0	0	0
70 > u >= 40	0	0	0	0	0	0
40 > u >= 5	0	8	3	0	0	0
5 > u	0	0	0	0	0	0









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Ultrasound Airborne Diagnostics

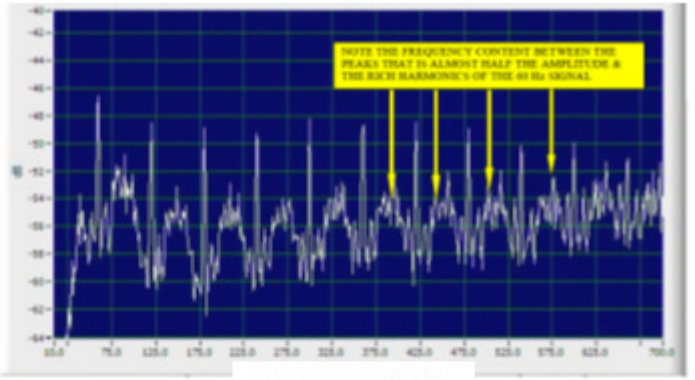
Electrical inspection

Discharge testing on:

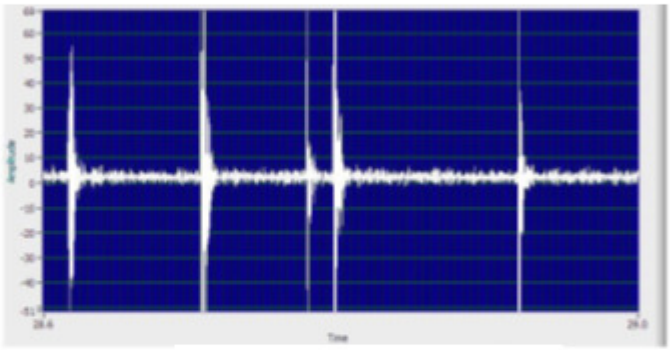
- Switchgears
- Power lines & isolators
- Transformers
- Circuit breakers

(Tracking, Arcing, Corona & mechanical looseness)

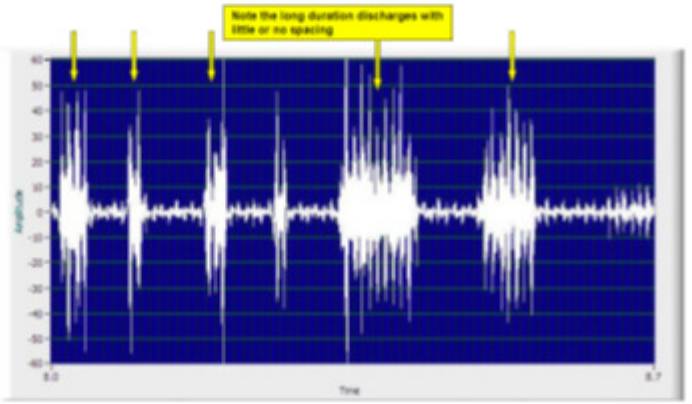
TRANSFORMER
Mechanically Loose



CORONA



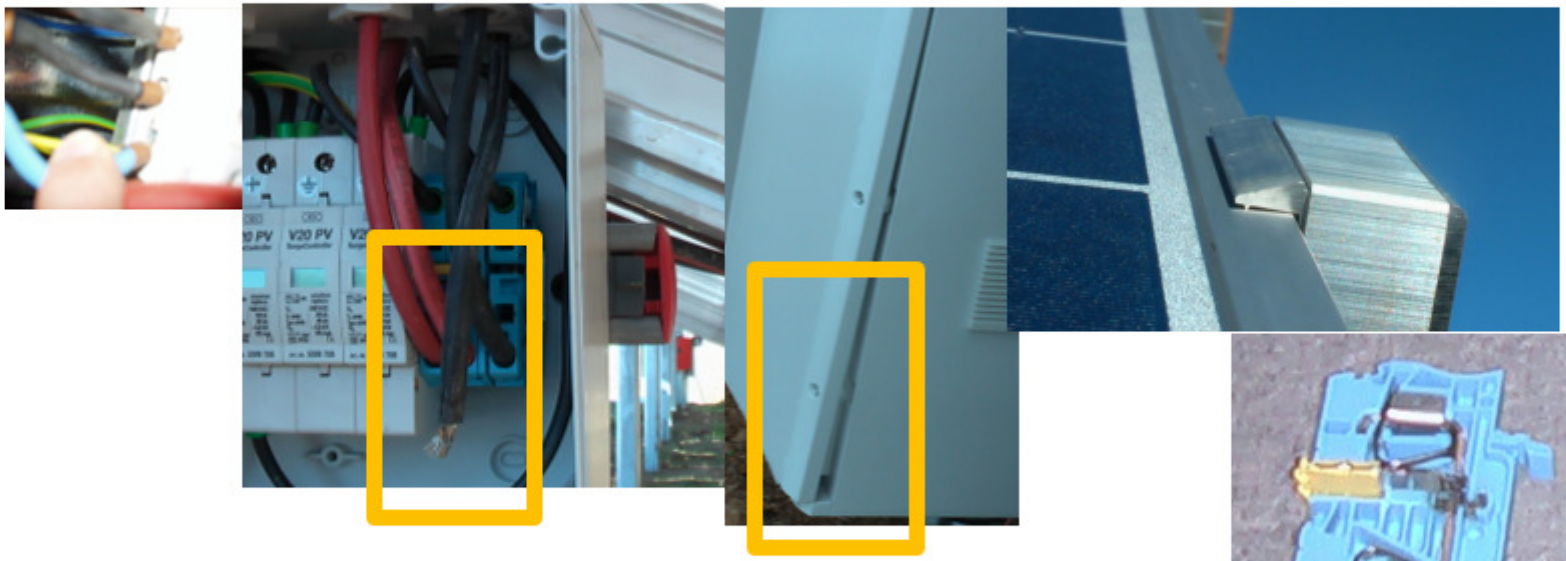
BAD TRACKING

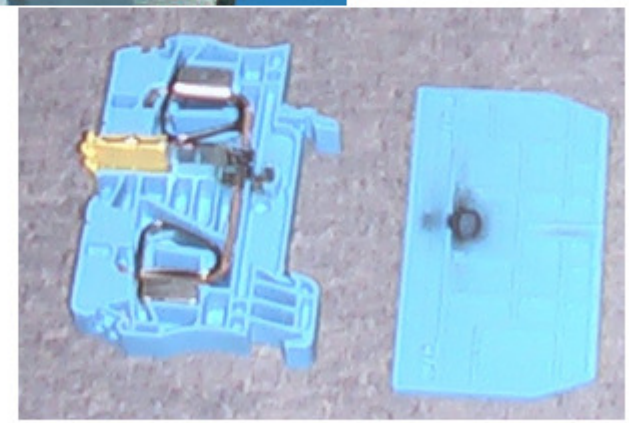


ARCING

UE SYSTEMS INC
The ultrasound approach

7. Troubleshooting
a. Electrical Installation





- **Weak connections**
- **Burned connectors and safety modules**
- **Cable Insulation absence**
- **Damaged doors and lack of IP protection**
- **Materials Incompatibility**

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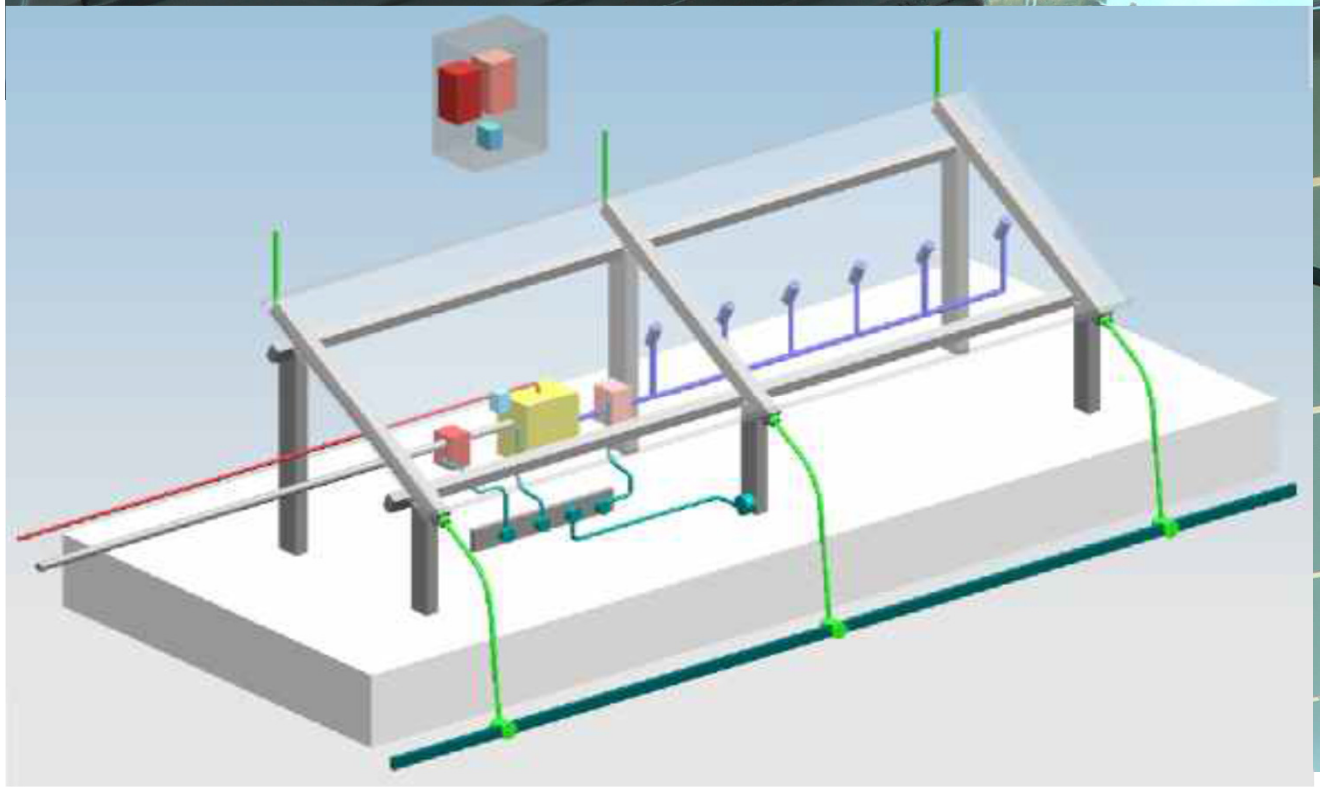
Lightning & Bonding absence



b. Mechanical and Static audits

- Mechanical connections inspection (Nm)
- Vibration Testing
- Bending arrow of panels limits (laser)
- Pull-up test (4th phase of the standard)
- Deformation measurement in static & alternating loads under full load

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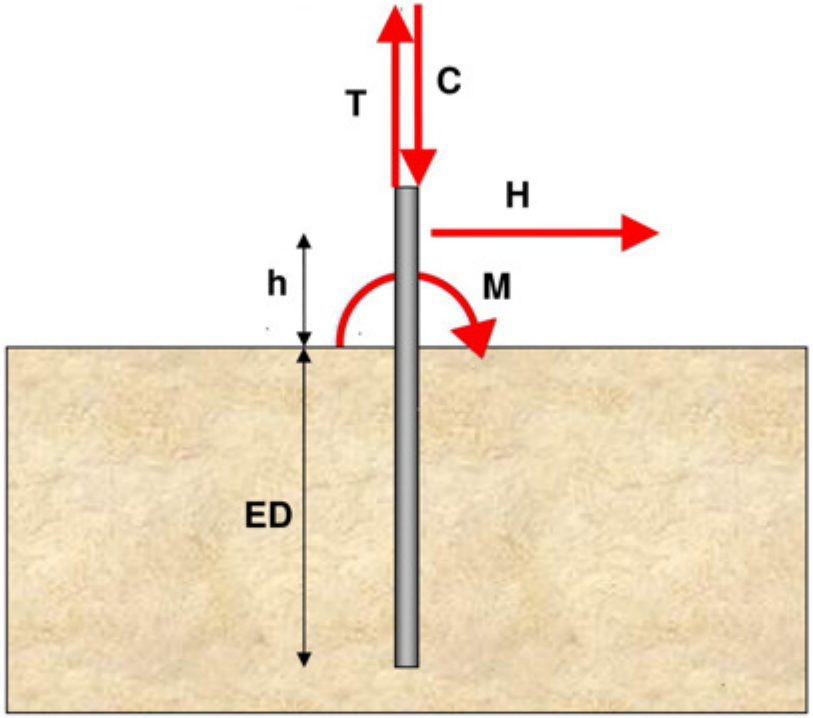
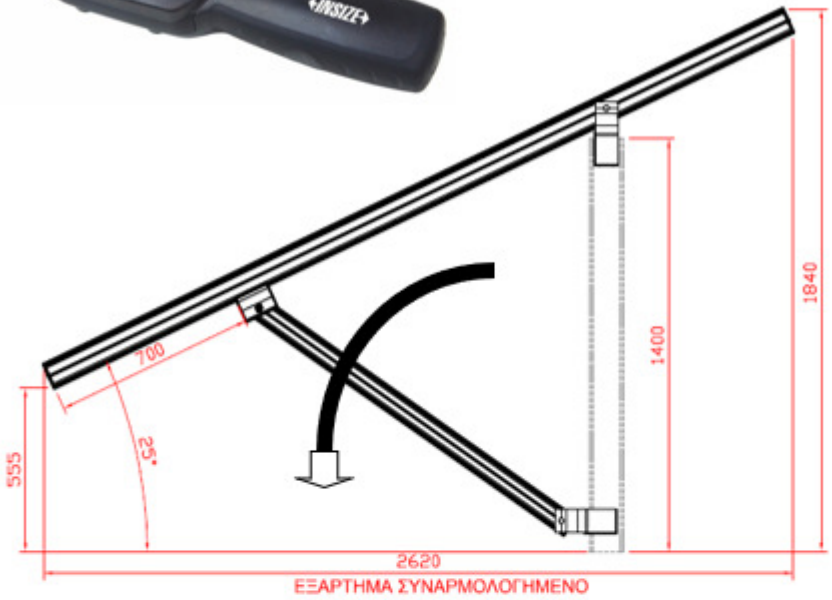
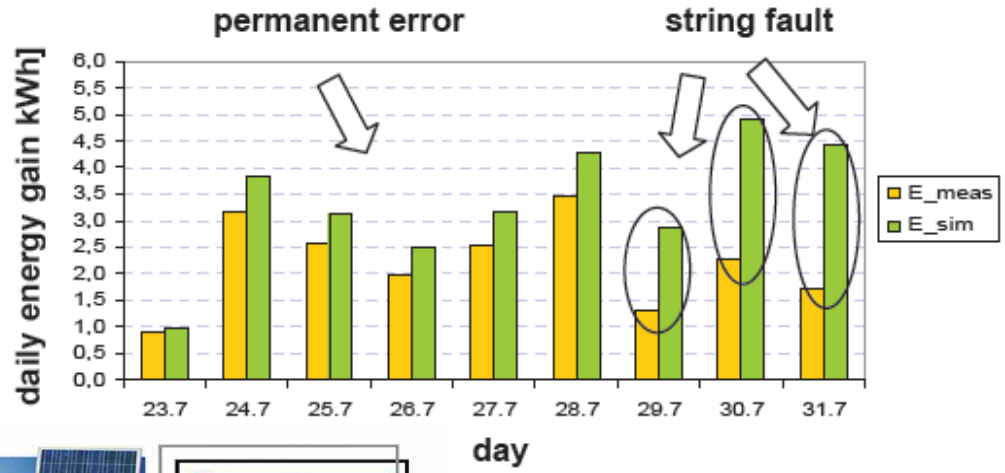
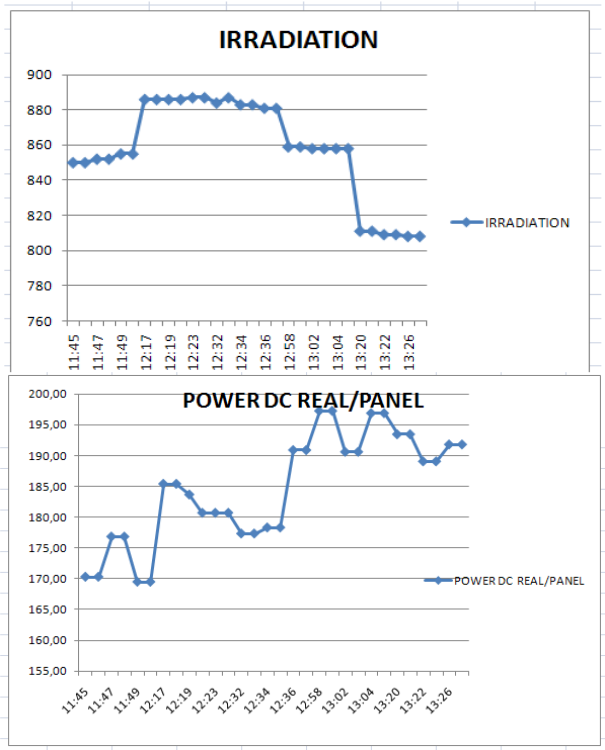
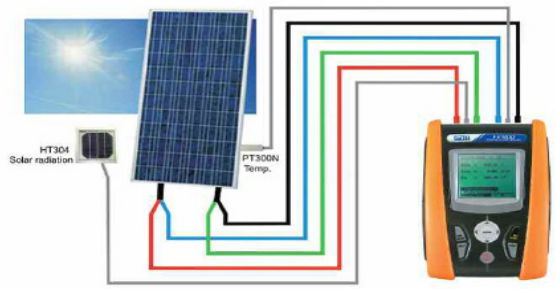




8. PV panels & Inverter performance

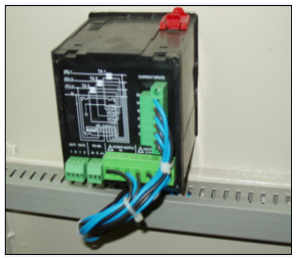


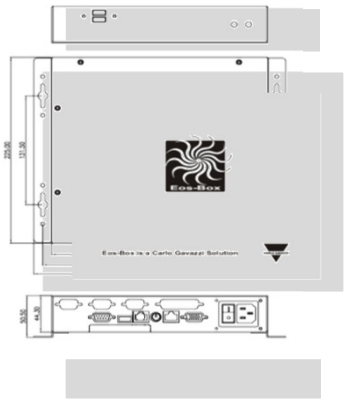




- Comparison PV panels performance with ideal operating conditions
- Comparison of the inverter performance with the nominal manufacturer technical characteristics.
- Recording of the Solar radiation and temperature with Specific Data-Loggers

9. Recording & Energy Remote Monitoring





- PQ Analyzer connection with the IT network and Operating control system of the energy and industrial signals according the IEC 61724 standard
- Independent monitoring system connection DC/AC (Eos-Array, Eos –Box)

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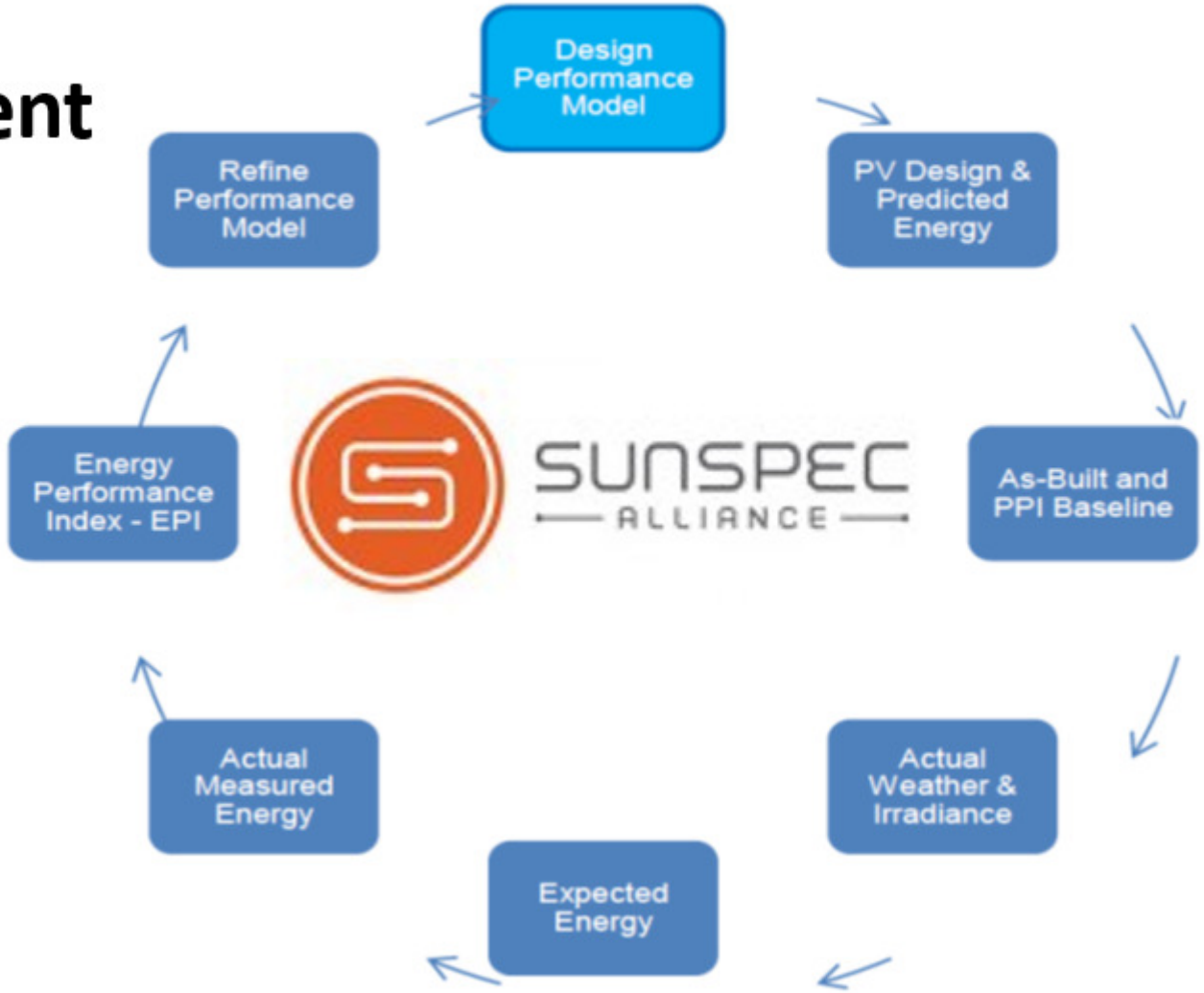
10. Assesment

of Operational Commissioning & Sustainability



Solar Plant Life Cycle

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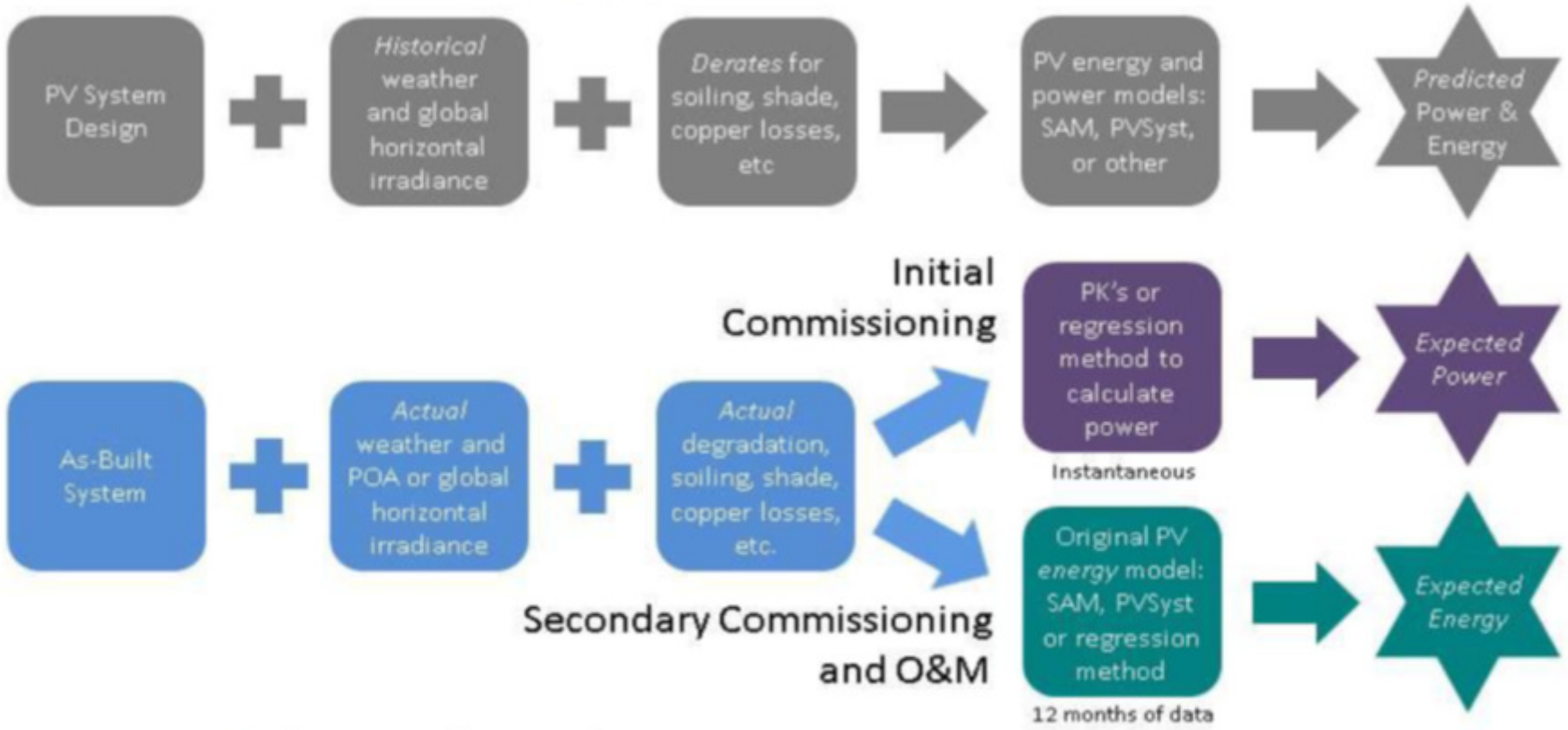

Expected Power → $\frac{\text{Measured power}}{\text{Expected power}}$ = PPI (Power Performance Index)

Expected Energy → $\frac{\text{Measured energy}}{\text{Expected energy}}$ = EPI (Energy Performance Index)

Recommended PV Lifecycle Performance Metrics

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Commissioning for PV Performance Best Practice Guide

Monitoring Indicators

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$$\textit{Expected ac Energy } E_{EXPECTED} = A + (Temp \times Irrad \times B) + (Irrad \times C) + (Irrad^2 \times D)$$

where A, B, C and D are coefficients calculated by the regression analysis.

$$\textit{Expected AC output power } P_{EXPECTED} = A + (Temp \times Irrad \times B) + (Irrad \times C) + (Irrad^2 \times D)$$

Baseline

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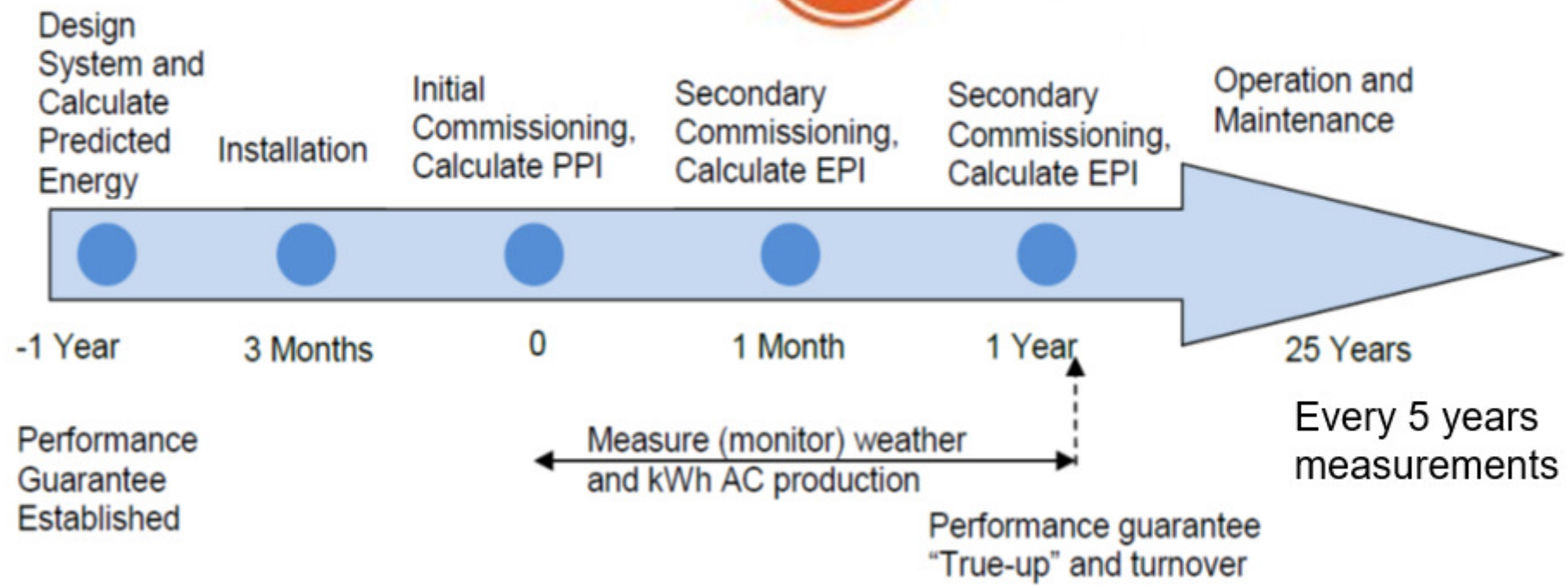

Life sequence of a PV system

The Operational Commissioning report is made only by second party specialized consultants with the appropriate certifications using specific calibrated analyzers, testers, tools and applications & NEVER by CERTIFICATION BODIES

The Operational Commissioning includes not only the Specific measurements according to the EN62446 standard, but also the international best practices with the baseline calculation of any photovoltaic park separately taking into consideration:

- **The microclimate of the area**
- **The specific construction features (geomorphology-topography of the area, the technical specifications of materials, construction practices etc.)**
- **Viability evaluation using LCCA & LCOE methods.**

KYANIDIS ENERGY has the Know-How and the equipment to be able to undertake the operational commissioning of large scale Photovoltaic Parks using the holistic approach of measurements

10th International Conference for European Energy Managers
30th September / 1st October 2020, Athens, Greece

Operational Commissioning of Photovoltaic systems

Thank you!

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