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Energy Efficiency Days

# FREQUENT OBSERVED FAILURES AND PERFORMANCE IMPROVEMENT RECOMMENDATIONS FOR THE PHOTOVOLTAIC POWER SYSTEMS INSTALLED IN TURKEY


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# The Fraunhofer-Gesellschaft

## Largest Organization for Applied Research in Europe

- non-profit registered society (not a commercial company)
- 66 institutes and research units
- Staff of nearly 24,000
- Fraunhofer ISE is second-largest institute






Fraunhofer ISE

# Fraunhofer Institute for Solar Energy Systems ISE
## Facts and figures

- Established: 1981
- Largest solar energy R&D institute in Europe
- Directors:

  Prof. Dr. Hans-Martin Henning
  Dr. Andreas Bett


**Key figures for 2017**

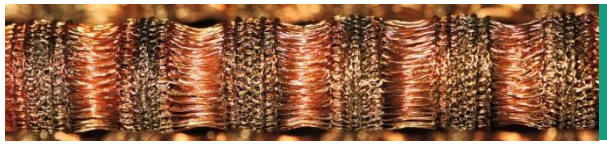
- Staff: 1202
- Budget incl. invest.: 89,4 Mil. €
- Industry revenue: 23 %
- Basic funding: 12 %

# Fraunhofer Institute for Solar Energy Systems ISE

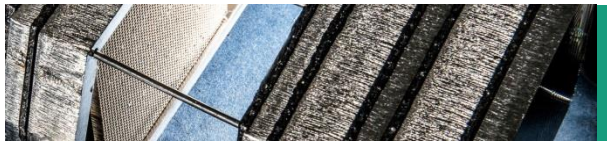
## Areas of Business

**PHOTOVOLTAICS**
- Silicon Photovoltaics
- III-V and Concentrator Photovoltaics
- Emerging Photovoltaic Technologies
- Photovoltaic Modules and Power Plants

**SOLAR THERMAL TECHNOLOGY**



**BUILDING ENERGY TECHNOLOGY**



**HYDROGEN TECHNOLOGIES**

**ENERGY SYSTEM TECHNOLOGY**







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# PV Power Plants
## LCOE and Performance Ratio

### Levelized Costs of Energy

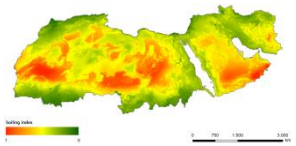
LCOE : ——————

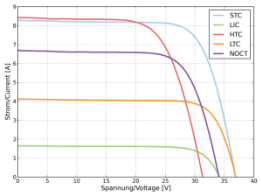

### Performance Ratio

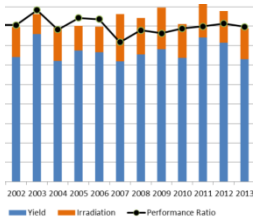

PR : ——————

# PV Power Plants
## Quality Assurance Services

**Project Development** → **Engineering** → **Procurement** → **Construction Commiss.** → **Operation**






- Solar ressource assessment
- Environmental stress assessment
- Site analysis
- Feasibility studies
- Self-consumption potential

- Yield assessment, including bifacial
- Component benchmarking
  - Module power & energy rating
  - Inverter testing

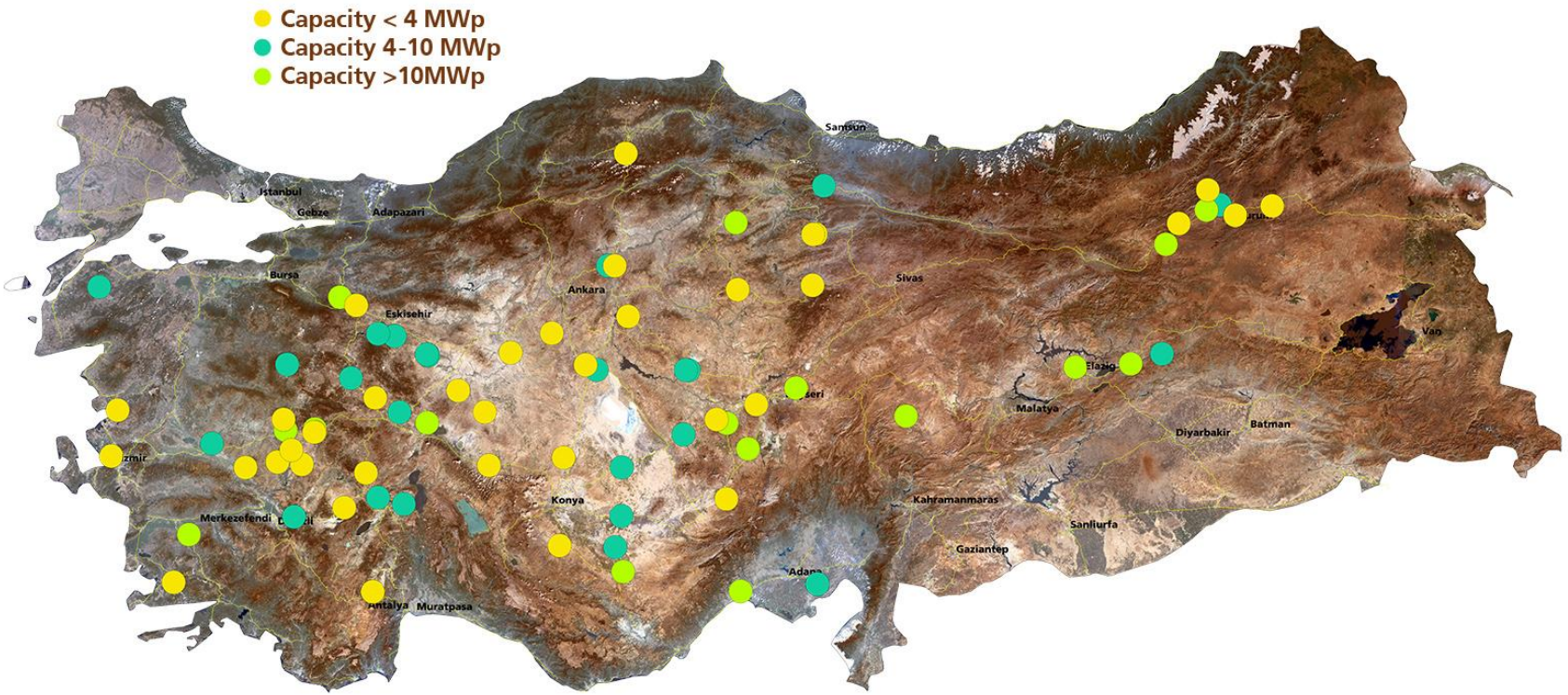
- Representative module sampling and checks
  - performance
  - reliability
  - workmanship

- Visual inspection during construction
- Final acceptance test

- Performance monitoring
- Performance check
- Repowering
- Failure analysis
- Market value assessment

# Quality Assurance of PV Power Plant

## Locations in Turkey over 70 different Photovoltaic Power Plant projects (~ 400 MWp in total)



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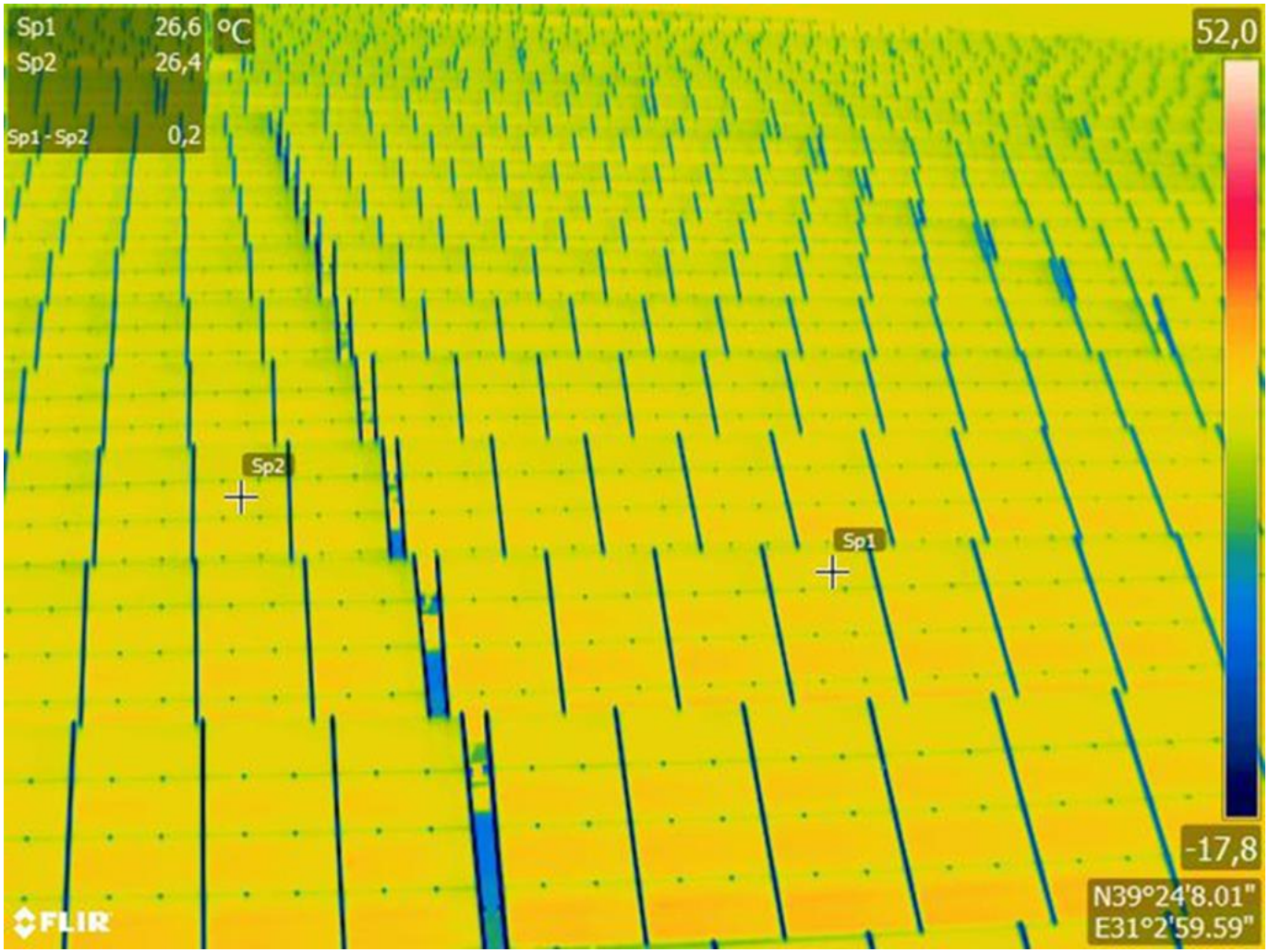
# Testing during Final Acceptance Test



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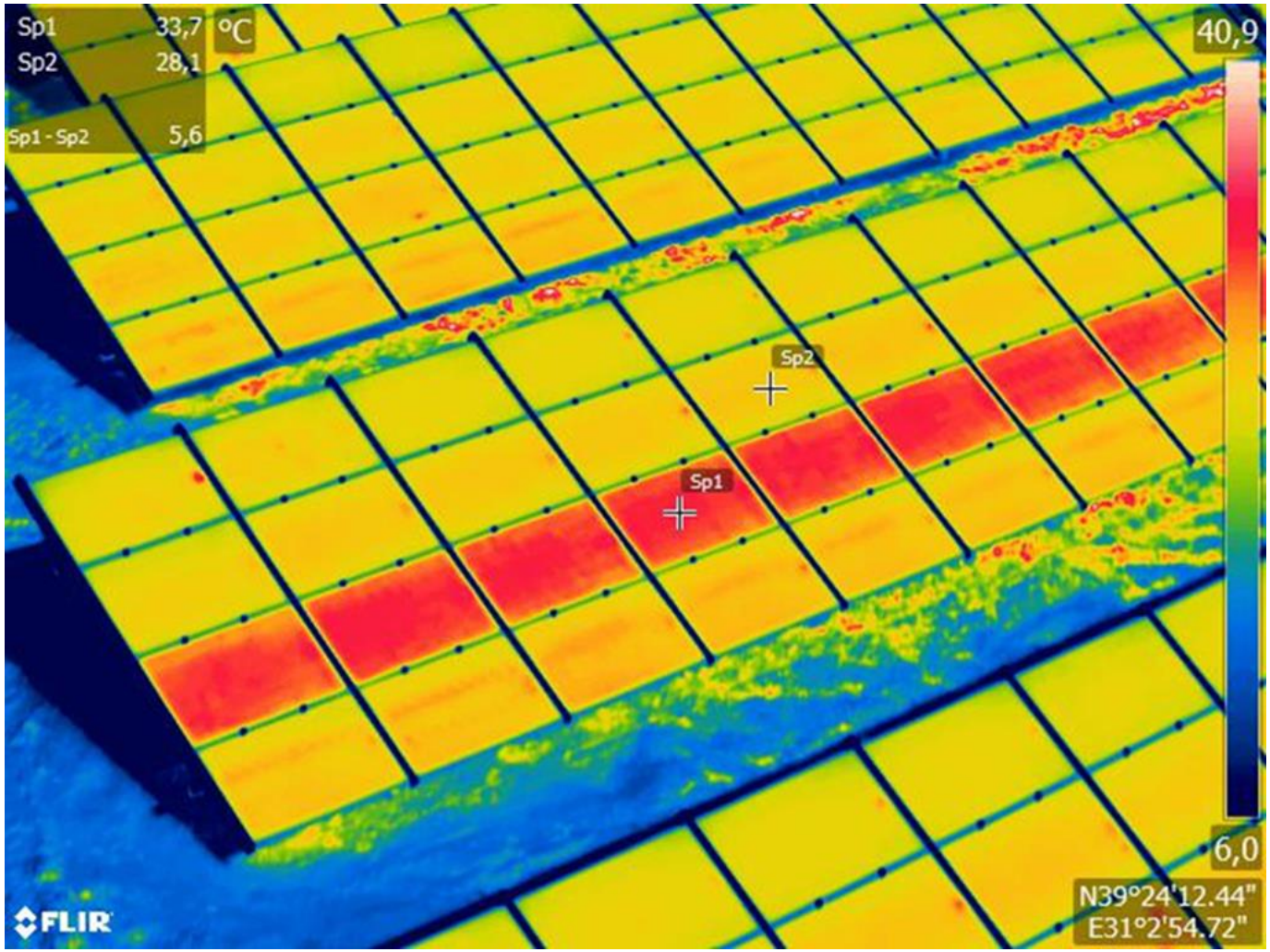
# Testing during Final Acceptance Test



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# System Inspection and Testing

- Heated cable in combiner box




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# System Inspection and Testing

- Heated cable in combiner box

## Measurements

| | | |
|---|---|---|
| Bx1 | Max | 82,9 °C |
| | Min | 15,8 °C |
| | Average | 59,2 °C |
| Sp1 | | 49,8 °C |
| Dt1 | Bx1.Max - Sp1 | 33,1 °C |

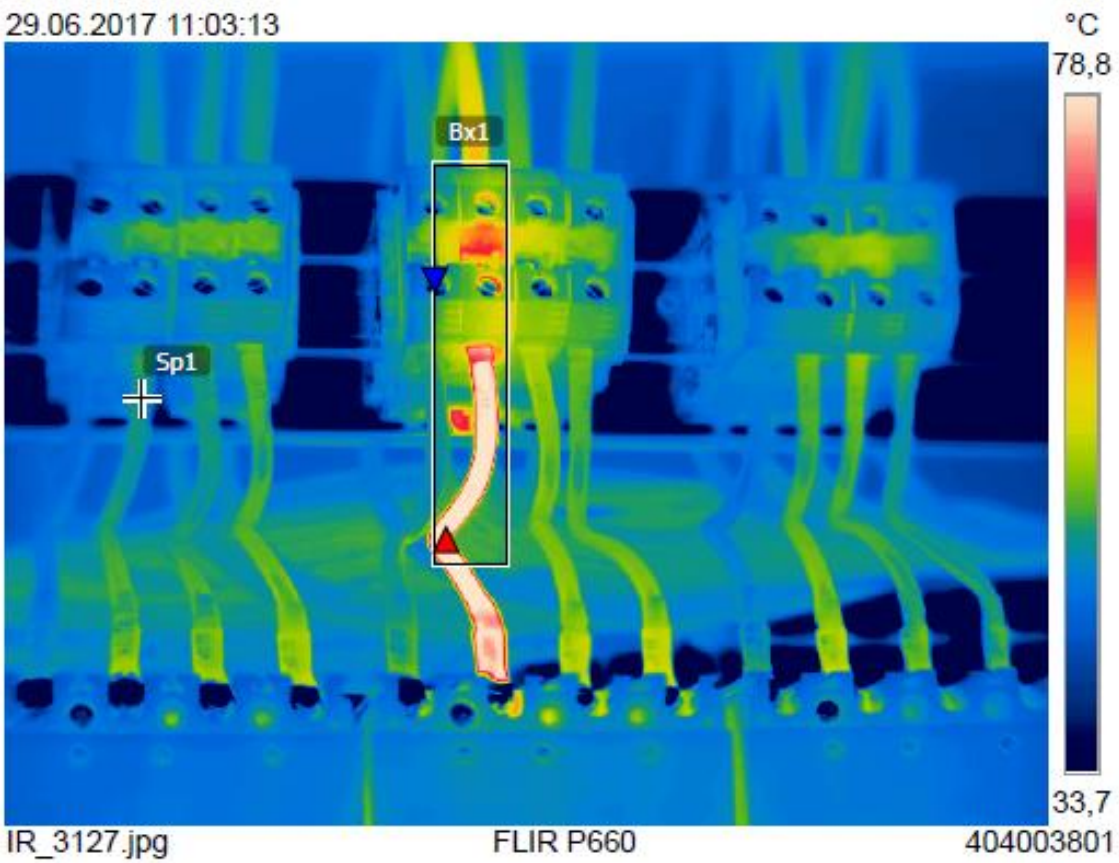
## Parameters

| | |
|---|---|
| Emissivity | 0.95 |
| Refl. temp. | 15 °C |

## Geolocation

| | |
|---|---|
| Location | N 37° 48' 15.19", E 34° 39' 42.12" |

http://maps.google.com?z=17&t=k&q=37.8042,34.6617



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# Recommendations for Maintenance

## Shading by vegetation

# Example of IR imaging

- Hot spot caused by shading through plants

## Measurements

| | | |
|---|---|---|
| Bx1 | Max | 94,9 °C |
| | Min | -9,6 °C |
| | Average | 39,7 °C |
| Sp1 | | 40,7 °C |
| Dt1 | Sp1 - Bx1.Max | -54,2 °C |

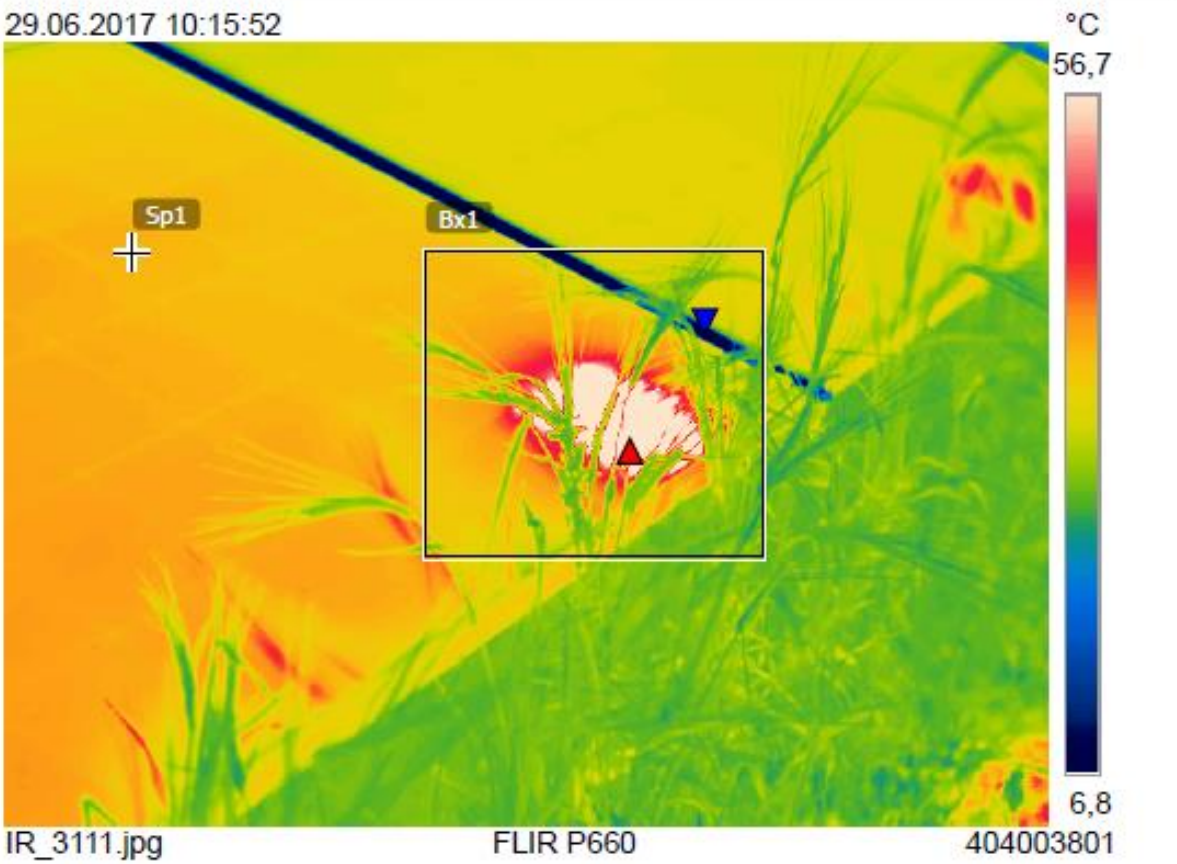
## Parameters

| | |
|---|---|
| Emissivity | 0.95 |
| Refl. temp. | 15 °C |

## Geolocation

| | |
|---|---|
| Location | N 37° 48' 14.04", E 34° 39' 38.06" |

http://maps.google.com?z=17&t=k&q=37.8039,34.6606



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# Recommendations for Maintenance

## Shading by vegetation

# Recommendations for Maintenance




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# Evaluation of Performance Ratio

## Recommendation:

- Precise Irradiance Measurement
- Highly available Data Acquisition System




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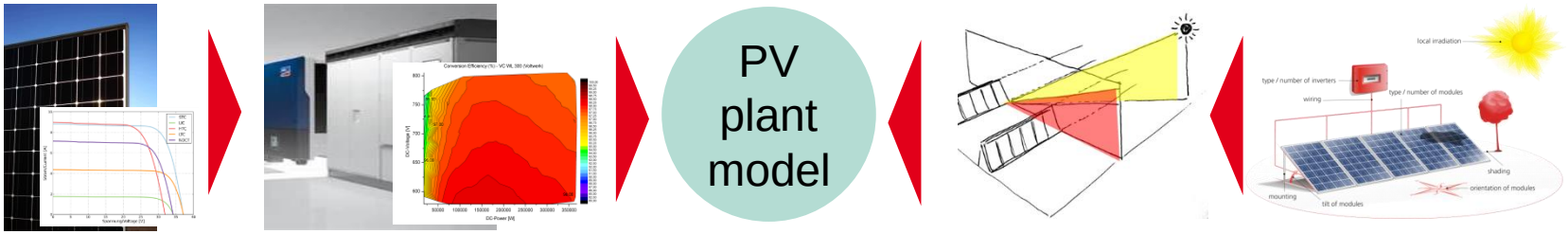
# Testing during Final Acceptance Test
## Performance Evaluation of the PV Plant

## Independent performance verification in 3 steps:

### 1: Model of the plant as built




module and inverter characteristics
e.g. temperature and irradiance dependence, efficiency

plant construction
e.g. orientation, tilt, shading and wiring losses

### 2: Validation of PV plant monitoring sensors (Irradiance and temperature)

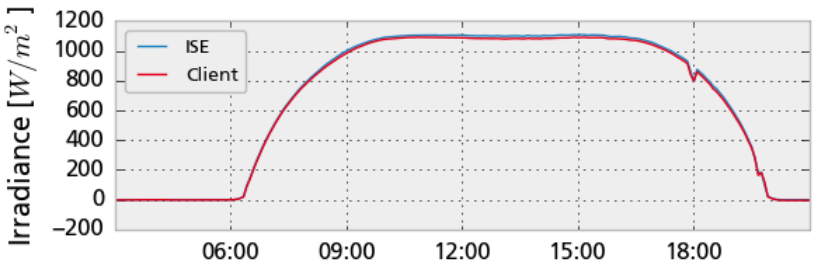



Fig. 1: Measured irradiance of ISE (red) and client (blue) sensor

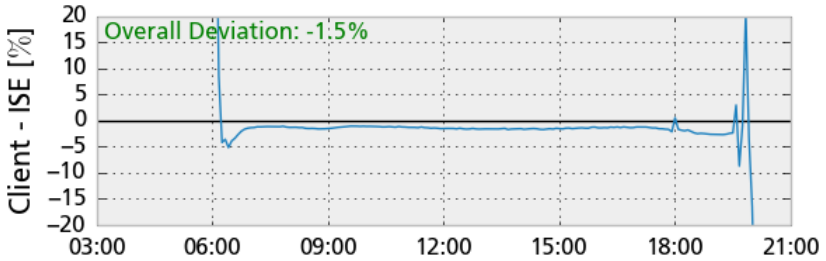



Fig. 2: Comparison of ISE and client pyranometer values



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# Testing during Final Acceptance Test
## Performance Evaluation

### 3: Plant performance: modelled vs. measured data

on-site measured irradiance and temperature data

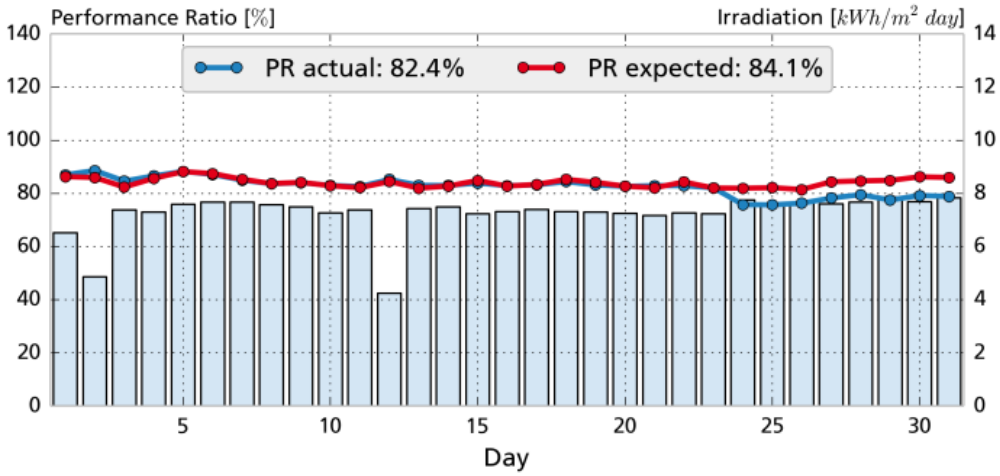
PV plant model

modelled PR

measured PR

PR

comparison and results




- Comparison of actual (measured) and expected (modelled) PR



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# Conclusion

## Quality is the key success for high performing PV Power Plants

- Yield assessments are independent check of the planning documents and provide the investors a precise yield estimation for the financial model
- Module testing shows poor module quality and deviation to rated power
- System inspections during the installation phase of the projects identifies weak points very early
- Final acceptance tests of the system are reducing technical risks during commissioning and start of the project
- Performance Monitoring ensures performance and financial returns during long-term operation of the system.

# Conclusion

## Return on Investment (ROI) strongly depends on the Quality of the PV Power System

In order to maintain and ensure a high plant quality in the long-term, the following items are important:

- Module must be chosen carefully and have to meet the state of the art
- Shading and soiling of the modules must be avoided
- The quality and reliability of the inverters must be very high
- The complete installation of the system must be carried out professionally
- In order to ensure long-term operation with high performance, the operation of the plant must be monitored very precisely

❖ Please note:

1 percent lower system output, e.g. due to poor or shaded or soiled modules, also leads to 1 percent lower performance

➢ Every percent counts to secure you investment!

# Thank You Very Much for Your Attention!

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