GOSSEN METRAWATT

Safety through Competence

PV

Guidelines

Photovoltaics

PHOTOVOLTAICS

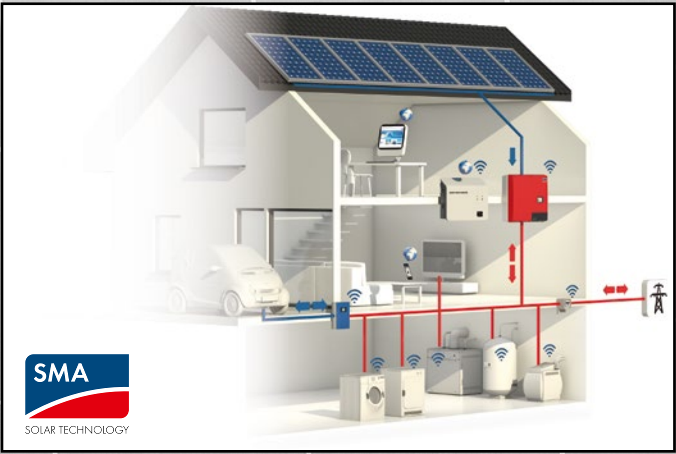
The field of photovoltaics has experienced rapid development since its beginnings in recent years. Insight and growing knowledge regarding the finite nature of fossil fuels and nuclear energy sources, as well as their consequences for the environment, have reawakened interest in solar technology.

Studies reveal that current use of PV technology has just begun and will evolve extensively through continuous growth. The renewable energy sources act supports autonomous generation of ecologically friendly energy.

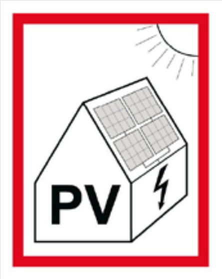
In actual practice, uncertainty frequently prevails about which normative requirements have to be adhered to when installing and troubleshooting PV systems. The PV Signpost offers assistance for routine daily work.

Photovoltaics is a means of generating electrical voltage using photon energy from the sun.

Schematic Diagram of a PV System



Source: SMA, Kassel



Identification of Buildings with PV Systems

An identifying sign should be installed in close proximity to the distributor cabinet or service lines (at least 148 x 105 mm).

PHOTOVOLTAIC EFFECT

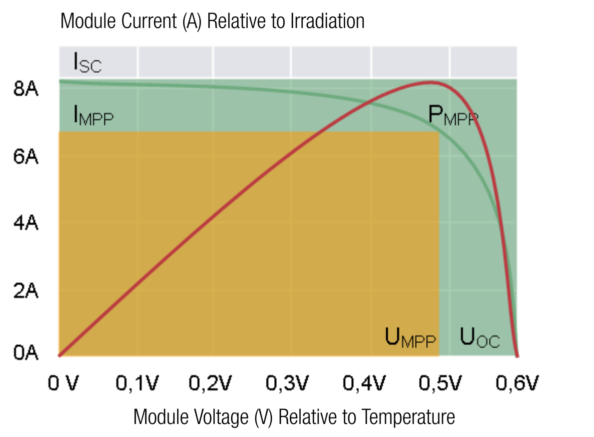
The photovoltaic effect is the direct transformation of light into electrical energy with the help of solar cells, i.e. solar energy is converted into electrical energy.

TEMPERATURE / IRRADIATION

Electrical quantities and the characteristic curves of the modules depend upon temperature and irradiation. Module current is directly dependent on the amount of irradiation, and module voltage is influenced for the most part by module temperature.

Characteristics of a PV Generator

MPP Maximum power point
I_{SC}… Short-circuit current
I_{MPP}…Momentary maximum current
U_{OC} …Open-circuit voltage
U_{MPP} Momentary maximum voltage



IMPORTANT TERMINOLOGY

Characteristic Current-Voltage Curve (IU curve)

The characteristic current-voltage curve depicts PV generator performance under various load conditions in the form of a diagram. The characteristic curve depends upon momentary irradiance E and solar cell temperature.

Open-Circuit Voltage U_{OC}

Output voltage of a solar cell or a solar module in the no-load state, i.e. in the absence of current.

Short-Circuit Current I_{SC}

Current at a short-circuited solar cell or a short-circuited solar module, i.e. with an output voltage of 0 V.

Module Efficiency

Indicates the relationship of a solar module's output power to its radiant power input, relative to the module's surface area.

kWp

Kilowatt peak. However, the "p" does not designate peak power, but rather nominal power under standard test conditions (STC).

P_{mpp}

Maximum output power of a solar cell or a solar module with a given amount of irradiation and a specific solar cell temperature, i.e. at the maximum power point (mpp).

Reference Cell

A calibrated solar cell for measuring global irradiance G on a flat surface (standard AM 1.5 spectrum where G = 1 kW per sq. meter at 25° C)

Detailed overview of terminology:

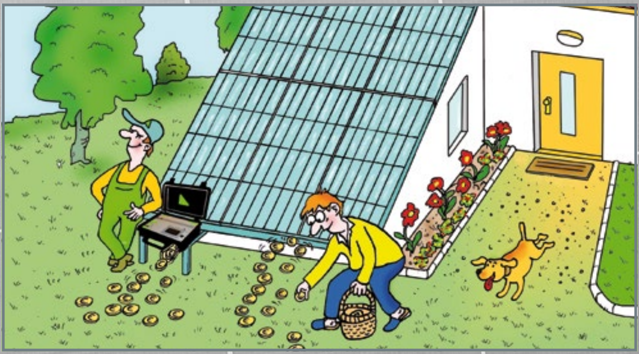
- **DIN EN 50521 –** Connectors for photovoltaic systems, – Safety requirements and tests
- **IEC 60050-826 –** Low-voltage installations – Definitions
- **DIN EN ISO 13943 –** Fire safety vocabulary

STC – STANDARD TEST CONDITIONS

In order to be able to compare different PV modules and cells with each other, standard test conditions have been established worldwide by means of which the characteristic curves of the solar cells are determined. The STCs make reference to IEC 60904 and DIN EN 60904 standards. Essentially, the characteristic curve is defined by the MPP value, short-circuit current and open-circuit voltage.

- Irradiance E with perpendicular incident light striking the surface of the module with 1000 W per square meter
- Cell temperature T of 25° C ± 2° K
- Defined light spectrum with an air mass (AM) of 1.5 (the unit of measure AM is defined in part III of the IEC 904-3 standard and quantifies the additional distance traveled by the sunlight in the case of inclined incidence instead of perpendicular incidence through the atmosphere – in the case of AM 1.5, the distance is 50% greater than with perpendicular incidence).
  (Air mass is equal to 1 at the equator, and roughly 1.5 in Europe.)

Note: STCs are theoretical quantities and are not actually achieved in the specified quality. NOCT conditions have been created in order to better represent these conditions. (NOCT conditions: radiant intensity of 800 W per sq. meter, ambient temperature of 20° C, wind speed of 1 ms^{-1}, PV system must be idling – EN 61215)



REGULATIONS AND DIRECTIVES FOR THE CONSTRUCTION OF PV SYSTEMS

Public Building Legislation (state building codes)

Formal, legal requirements

- Construction permits (state building codes): as a rule, no permit is required. Exceptions: for example systems on building facades, commercial PV systems on farm buildings (North Rhine – Westphalia)
- Building products and types, amongst other things approvals and test certificates

Substantive Legal Requirements

- Construction planning law
- Building codes regarding, amongst other things, insulation, fire prevention and lightning protection
- Ancillary building law regarding, amongst other things, protection of historic buildings and monuments

Technical Rules for Building Designs with Glass

DIN 18008 – Glass in Building – Design and construction rules
TRLV, TRAV, TRGS (e.g. asbestos)

VDE-AR-N100

VDE AR N100 is the basis for compliance with VDE codes of practice for planning, erection, production, operation, testing and maintenance of systems, equipment and products for power supply, including requirements for the qualification and organization of companies for the operation of electrical power supply networks. The VDE codes of practice serve as a basis for safe and reliable electrical power supply.

E VDE-AR-N 4105

Power generation systems connected to the low-voltage distribution network – Technical minimum requirements for connection to and parallel operation with low-voltage distribution networks

Technical Connection Regulations for the Distribution Network Provider

The technical connection regulations must be observed for systems which are being newly connected to the distribution network, as well as when customer systems are being expanded or modified. In particular, the technical connection regulations specify the obligations of the network provider, the installer and the planner, as well as the power customer and the power consumer.

SYSTEM PLANNING, EEG

PV Project Planning with DDS-CAD PV

Special software solutions are available which are suitable for planning photovoltaic systems. Solar technicians can plan and visualize PV systems for on-roof, in-roof and facade installation, as well as for setup in open areas, with the high performance DDS-CAD PV planning tool from GOSSEN METRAWATT's collaboration partner Data Design System (DDS). In addition to realistic simulation of the sun's path, the software generates complete system documentation including setup plans, a system schematic and string plans.

The integrated Polysun Inside tool allows for reliable yield prognoses. Automatic inverter allocation, as well as a comprehensive module and inverter database, are also available.

If desired, the rest of the electrical installation (distributor, electrical circuits, cable conduits, cabling, lightning protection etc.) can also be fully planned and calculated with DDS-CAD PV. An interface to GOSSEN METRAWATT test instruments is available.

Source: DDS-CAD

Shading caused by interfering objects is realistically represented by DDS-CAD PV as part of the function for simulating the sun's path.

EEG – German Renewable Energy Sources Act

The renewable energy sources act regulates procurement, transmission and billing of electrical power generated entirely from renewable energy sources (e.g. solar power and wind power) by the power utilities who operate networks for general power supply (network providers).

Core content: Discrimination-free access to the network, "no capping / upper limit" with regard to power, prices are legally guaranteed and fixed over a long period of time.

STANDARDS

IEC 60364-1
Erection of low-voltage installations
Part 1 – Fundamental principles, assessment of general characteristics, definitions

IEC 60364-6
Low-voltage electrical installations, Part 6 – Verification

EN 50110-1
Operation of electrical installations – General requirements

IEC 60364-7-712
Part 7-712 – Requirements for special installations or locations – Photovoltaic (PV) power systems

IEC 60904-2
Photovoltaic devices, Part 2 – Requirements for reference solar devices

VDE 0126-21 (Draft)
Photovoltaic in building

IEC 62446
Grid connected photovoltaic systems –
Minimum requirements for system documentation, commissioning tests and inspection

DIN EN 61730-1
DIN EN 61730-2
Photovoltaic (PV) module safety qualification,
Part 1 – Requirements for construction

IEC 61215
Crystalline silicon terrestrial photovoltaic (PV) modules –
Design qualification and type approval

IEC 61646
Thin-film terrestrial photovoltaic (PV) modules –
Design qualification and type approval

IEC 82/571 (Draft)
Testing the power coefficient of photovoltaic (PV) modules and energy measurement
Part 1 – Power measurement relative to irradiance and temperature, as well as performance measurement

DIN EN 62108
Concentrator photovoltaic (CPV) modules and assemblies –
Design qualification and type approval

TEST REQUIREMENTS PER IEC 62446

AC Systems

- Testing of all AC circuits for compliance with requirements per EN/IEC 60364-6

DC Systems

- Test functional ground electrode and equipotential bonding conductor (PV generator frame) for continuity, including the connection to the main grounding terminal ⇨ low-resistance test
- Test polarity of all DC conductors and their connections and inspect for correct identification
- Test/measure open-circuit voltage of each string under stable irradiance conditions (< 5%), compare identical strings
- Test/measure short-circuit current of each string under stable irradiance conditions (< 5%), compare identical strings

Note: Make sure that all PV strings are isolated from each other – disconnecting devices and switchgear must be open!

- Functional inspection for correct installation and connections, mains failure test
- Insulation resistance for DC circuits – 2 test procedures in accordance with VDE:
  "**Test 1** between the negative electrode of the PV generator and ground, followed by testing between the positive electrode of the PV generator and ground."
  "**Test 2** between ground and the negative and positive electrodes of the PV generator, while the electrodes are short-circuited."

Note: Disconnect overvoltage arresters before performing the measurements!

Minimum Values for Insulation Resistance

Test Procedure	System Voltage, ($U_{OC\ stc}$ x 1.25) V	Test Voltage, V	Smallest Insulation Resistance, MΩ
Test Procedure 1	< 120	250	0.5
	120 to 500	500	1
	> 500	1000	1
Test Procedure 2	< 120	250	0.5
	120 to 500	500	1
	> 500	1000	1

Source: DIN EN 62446

SYSTEM DOCUMENTATION REQUIREMENTS PER IEC 62446

After installation or periodic testing of grid-connected PV systems, documentation with basic system data must be prepared for the customer, the inspector or the maintenance engineers.

Basic System Data

- Rated system power (kW DC or kVA AC)
- PV modules and inverter (model, manufacturer and quantity)
- Date of installation and initial start-up
- Customer name
- Address of installation location

Information on the System Developer

- Company name, contact person, address, phone number and e-mail address

Information on the System Installer

- Company name, contact person, address, phone number and e-mail address

REQUIREMENTS FOR FIRE PROTECTION AT PV SYSTEMS

Source: EATON

Fireman's Switch (EATON)

The fireman's switch is recommended as an additional DC switching point for safe firefighting. This enabling device must be connected in parallel to the mains disconnector.

VDE-AR-E 2100-712 Enabling requirements in the DC section of PV systems

VDS 2033 Electrical systems at plant locations with risk of fire and other comparable risks, amongst others laying direct current cables.

VDS 2216 Fire prevention measures for roofs, leaflet for planning and execution.

VDE-AR-E 2283-4 Requirements for cables for PV systems (type PV1-F)

STANDARDS FOR THE USE OF RCDS IN PV SYSTEMS

DIN VDE 0100-482 – Protection against fire where particular risks or dangers exist

DIN VDE 0100-705 – Agricultural and horticultural premises

DIN VDE 0100-712 – Part 7 – Requirements for special installations or locations - Solar photovoltaic (PV) power supply systems

INITIAL START-UP

The party responsible for setting up the PV system must write a report for each start-up procedure. Important report contents include measured values and system data.

Documenting measured values:

- Insulation resistance on the DC side
- Earth resistance of the system
- Open-circuit voltage of the generator
- Open-circuit voltage of the string
- Short-circuit current of the string
- Voltage drop over diode and fuse for systems with string diodes/fuses (generator terminal boxes)
- Optional measurement of characteristic curves of the individual strings
- Preparation of thermograms for the PV generator, as well as switchgear and fusing

PHOTOVOLTAIC SYSTEM CERTIFICATION

System certification has been developed by BSW-Solar together with the Central Association of German Electrical and Information Technology Trades (ZVEH) in order to verifiably document high quality installation of solar systems for the customer. Key components utilized in the solar power system and services rendered by the installer are documented in these records (PV system test report). Interested, qualified installation technicians can register at the following website:
www.photovoltaik-anlagenpass.de.

Design and Planning per RAL-GZ-966 Quality and test specifications:

P1: Components for photovoltaic systems
P2: Photovoltaic system planning
P3: Photovoltaic system design
P4: Service and operation of photovoltaic systems

Source: BSW, ZVEH, RAL

LIGHTNING AND OVERVOLTAGE PROTECTION

DIN EN 62305-2
Protection against lightning – Part 2: Risk management

DIN EN 62305-3, (supplement 5)
Part 3: Protection against lightning and overvoltage for PV power supply systems

Instruction leaflet for PV electricians
Protection against lightning and overvoltage in PV systems on buildings, from BSW and ZVEH

VDS directives 2010-09
Risk oriented protection against lightning and overvoltage

DIN CLC/TS 50539-12
Part 12: Selection and application principles –
Surge protective devices connected to photovoltaic installations

In general it can be said that: “PV systems do not increase the risk of buildings being struck by lightning”, although if left unprotected, system components may fail as the result of lightning current and/or overvoltage. The consequences would involve lost revenue and repair costs. The respective building codes in the various regions of Germany specify protection class III lightning protection system (LPS) for safety reasons when PV systems are installed on public buildings such as hospitals or schools.

Advantages of protection against lighting and overvoltage:

- Fire prevention and protection against destruction of the PV system and the building
- Continuous availability of the PC system
- Secure investment without any decrease in revenue
- Protection against injury to living beings within and in proximity to the system

The lightning protection system consists of external and internal lightning protection, as well as overvoltage (surge) protection.

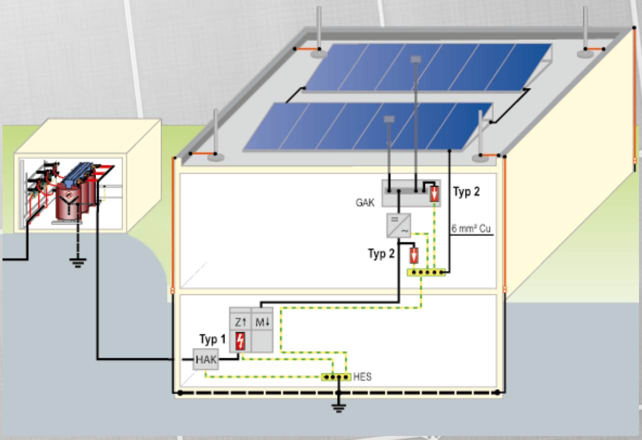
EN 62305-3 defines the degrees of protection provided for buildings with the four lightning protection levels, namely I through IV.

External Lightning Protection System

- With lightning current arresters which create a protection zone on the roof in consideration of clearances
- With diverters which conduct the lightning to the earthing system
- Lightning current is conducted into the ground via the earthing system.

Internal Lightning Protection System

- Type 1 lightning arrester for AC supply to the building
- Type 2 lightning arrester for protecting the inverter for AC and DC terminals
- Type 2 DC surge arrester in the generator terminal boxes for protecting the modules



Source: DEHN + SÖHNE GmbH + Co. KG.

INVERTER CERTIFICATION

VDE V 0126-1-1
Automatic disconnection device between a generator and the public low-voltage grid

DIN EN 62109-1
Safety of power converters for use in photovoltaic power systems – General requirements

DIN EN 62109-2
Safety of power converters for use in photovoltaic power systems – Particular requirements for inverters

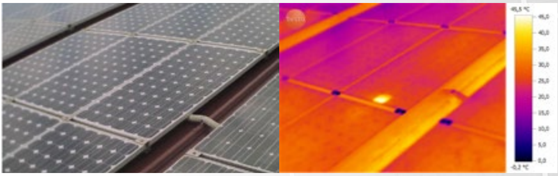
IR THERMOGRAPHY

By accurately measuring the temperature at the surface of a solar module, thermal imaging cameras allow for quick and efficient troubleshooting of a wide variety of defects.
Advantages include image-generating, contactless, non-destructive testing of the PV system during normal operation and the ability to scan large surfaces. For purposes of quality assurance, thermography should also be used to test the system after installation has been completed.

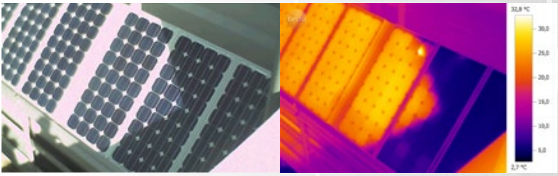
Amongst others, the following defects can be detected with the help of thermography:
Short-circuits in solar cells, contamination, penetration by moisture, cracks in cells or solar glass, bad contacts between the conductor strip and solar cells, defective bypass diodes, modules in no-load operation and unconnected modules, mismatches, i.e. power loss due to varying performance of the individual modules.

Standards and Directives

- **DIN 54190, Part 1-3** – Non-destructive testing – Thermographic testing Part 1: General principles, Part 2: Equipment, Part 3: Terms and definitions
- **DIN EN 13187** – Thermal performance of buildings – Qualitative detection of thermal irregularities in building envelopes – Infrared method
- **DIN EN 13829** – Thermal performance of buildings – Determination of air permeability of buildings – Fan pressurization method
- **DIN 4108, Parts 1 to 3** – Thermal insulation
- **DIN EN 473** – Non-destructive testing – Qualification and certification of NDT personnel – General principles



Hot Spot (approx.15 K above average temperature)

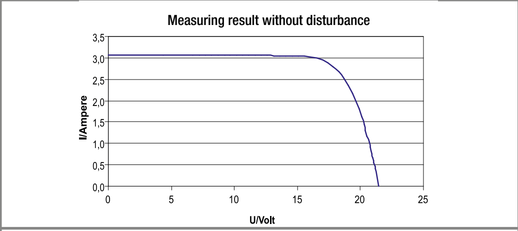


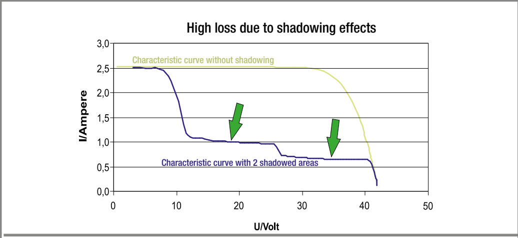
Shaded Cells or Cells Concealed by Contamination

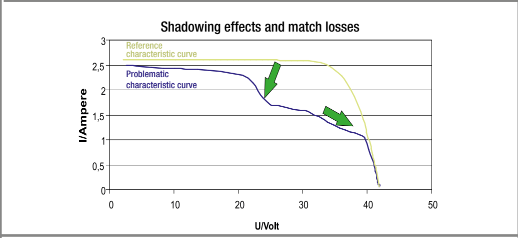
Not Every Hot Spot is a Defect – Thermograph of the Junction Boxes

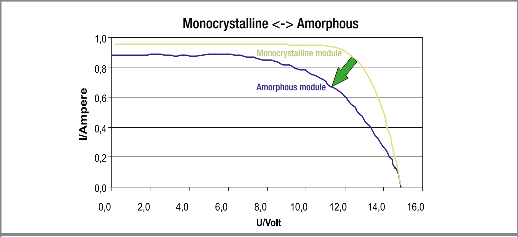
Source: testo AG

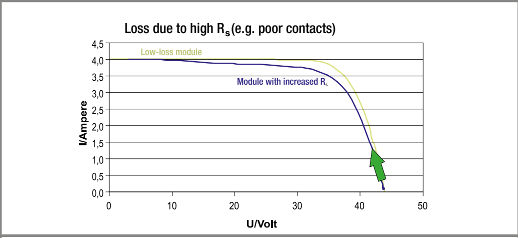
SAMPLE CHARACTERISTIC CURVES FROM ACTUAL PRACTICE

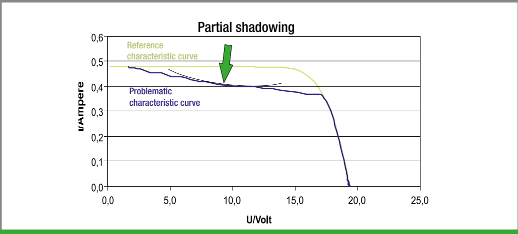












Source: PV Engineering

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