Benha University

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Faculty of Engineering at Shoubra
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Undergraduate Course

Solar Cells Fundamental

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Lecture (7)

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Solar Radiation Measurements

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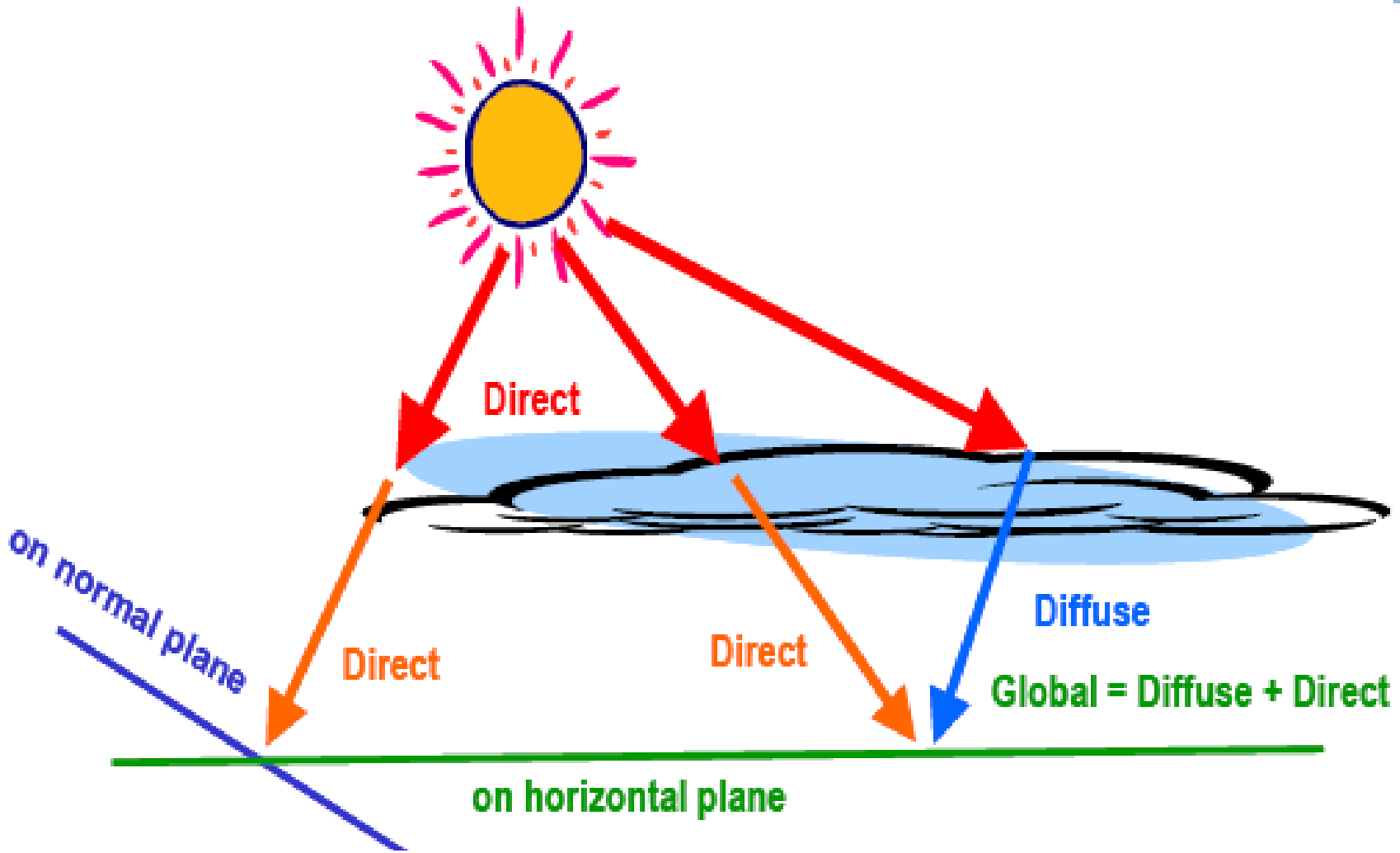
Measurement of Solar Radiation



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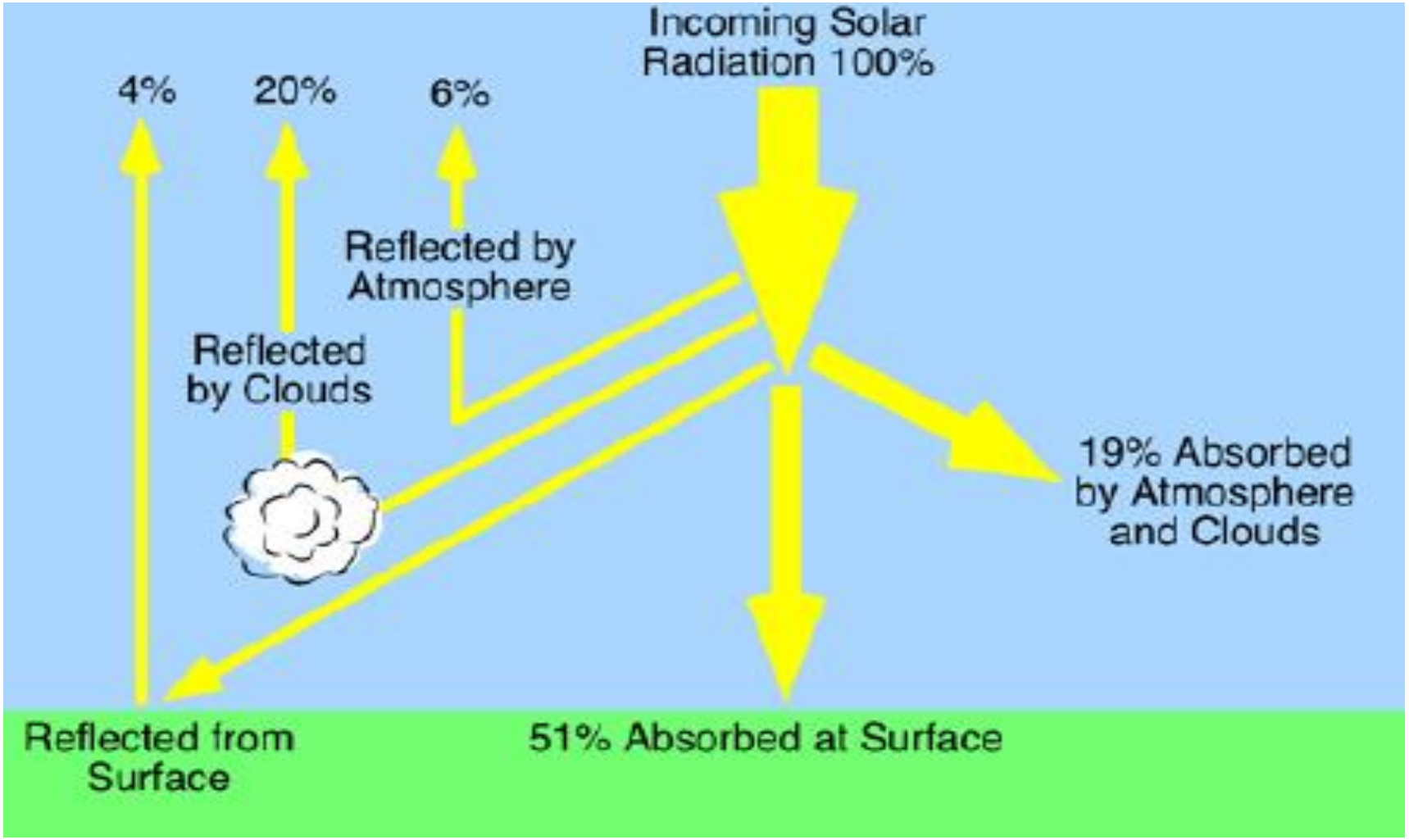

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Solar Radiation Measurement Devices

Global solar radiation

Pyranometer

Diffuse radiation

Pyranometer

Direct solar radiation

pyrheliometer

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1. Pyranometer

- Measure beam radiation + diffused radiation.
- Measure diffused radiation when shading ring is used.
- **Principles**
  - Black surface absorb
  - White surface reflect unnecessary heat.

2. Pyreheliometer

- Used to measure direct beam radiation.
- **Principles**
  - Temperature difference between black and white.
  - Converted into EMF (Electromotive force).
  - Proportional to energy incident on surface.

3. Sunshine recorder

- Use to measure duration of the day when there was bright sun shine give beam radiation.
- **Principle**
  - Glass concentrate solar radiation.
  - Paper receive solar radiation on it which is chemically treated.
  - Paper give burn mark, When the sun shine is present.

4. PV solarmeter

- Typically pyranometer measure solar flux intensity.
- **Principle PV cell**
  - Solar energy ⟶ solar cell ⟶ variable resistive load ⟶ current produced.
  - Moved in direction off sun.
  - Meter calibrated in watt per meter square.

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Array Design

- **The major factors influencing the electrical design of the solar array are as:**

1. The sun intensity.
2. The sun angle.
3. The load matching for maximum power.
4. The operating temperature.

How to Maximize the solar PV output ?

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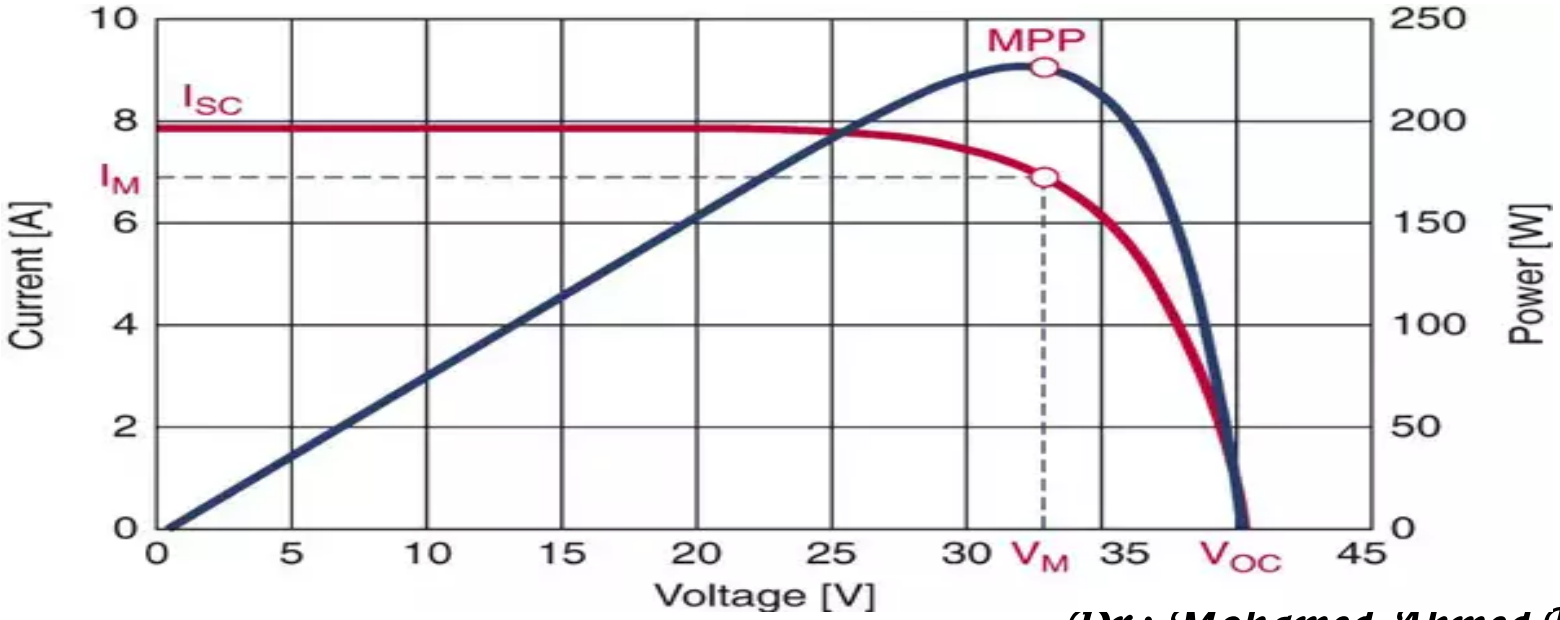
Maximize the solar PV output

- The best use of solar PV system is made by maximizing the output.
- First by mechanically orienting the panel for sun tracking to receive maximum solar radiation.
- Secondly by electrically tracking the operating point by manipulating the load.



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Maximum power point tracking (MPPT)

- To receive the maximum power, the load must adjust itself accordingly to track the maximum power point.
- Three possible strategies of operation of MPPT are:
  - By monitoring dynamic and static impedance.
  - By monitoring Power output.
  - By fixing output voltage.

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Lecture Summary

- PV mounting methods
- PV system design
- Solar radiation measurements
- Measurements devices
- Array design
- MPPT

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Standards, Calibration, and Testing of PV modules & solar cells

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Standardization - Technical Committees

1. **IEC Technical Committee TC82**

- was established in 1981. It is the most important International body regarding photovoltaic related standardization.

- The main tasks of TC82 are to prepare international standards for systems of photovoltaic conversion of solar energy into electrical energy and for all the elements in the entire photovoltaic energy system.

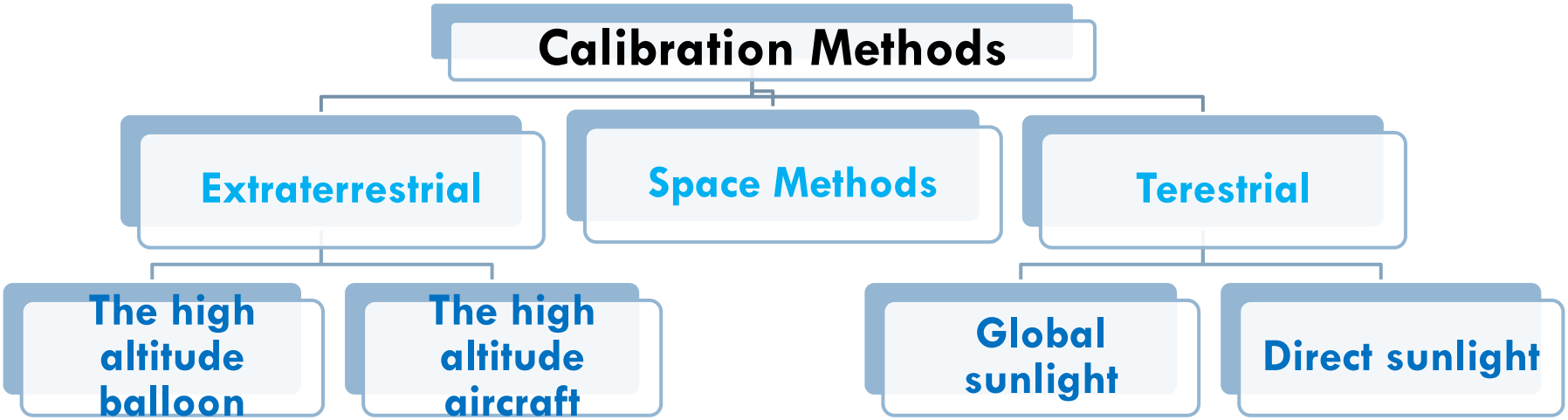
2. **ASTM Committee E44**

- on Solar, Geothermal and Other Alternative Energy Sources is composed of subcommittees that address specific segments within the general subject area covered by the technical committee.

- In the USA, the **National Electric Code (NEC)** contains sections that specifically cover solar-energy and distributed power generation systems.
- The **International Residential Code (IRC)** and the **International Energy Conservation Code (IECC)** reference related standards that apply if installing, respectively, a residential or commercial PV system.
- The **International Fire Code (IFC)** establishes solar provisions relating to fire access and fire safety.

Calibration

- Standard solar cells are used to set the intensity of solar simulators to standard illumination conditions, in order to electrically characterize solar cells with similar spectral response.
- The calibration methods of solar cells can be:



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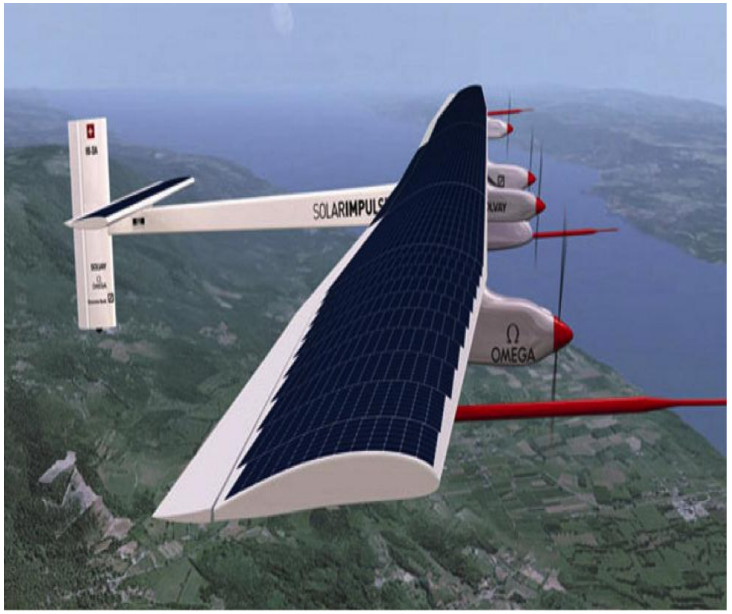
The high altitude balloon

- on board stratospheric balloons flying at altitudes of around 36 km.
- The illumination sun conditions are very close to 0 AM.
- The cells are directly exposed to the sun.
- The

The high altitude aircraft

- on board of an aircraft capable of flying at altitudes of 15-16 km.
- cells are mounted at the end cap of a collimating tube on a temperature controlled plate.
- data are corrected for:
  * the ozone absorption.
  * the geocentric distance.
  * extrapolated to the air mass value of zero.

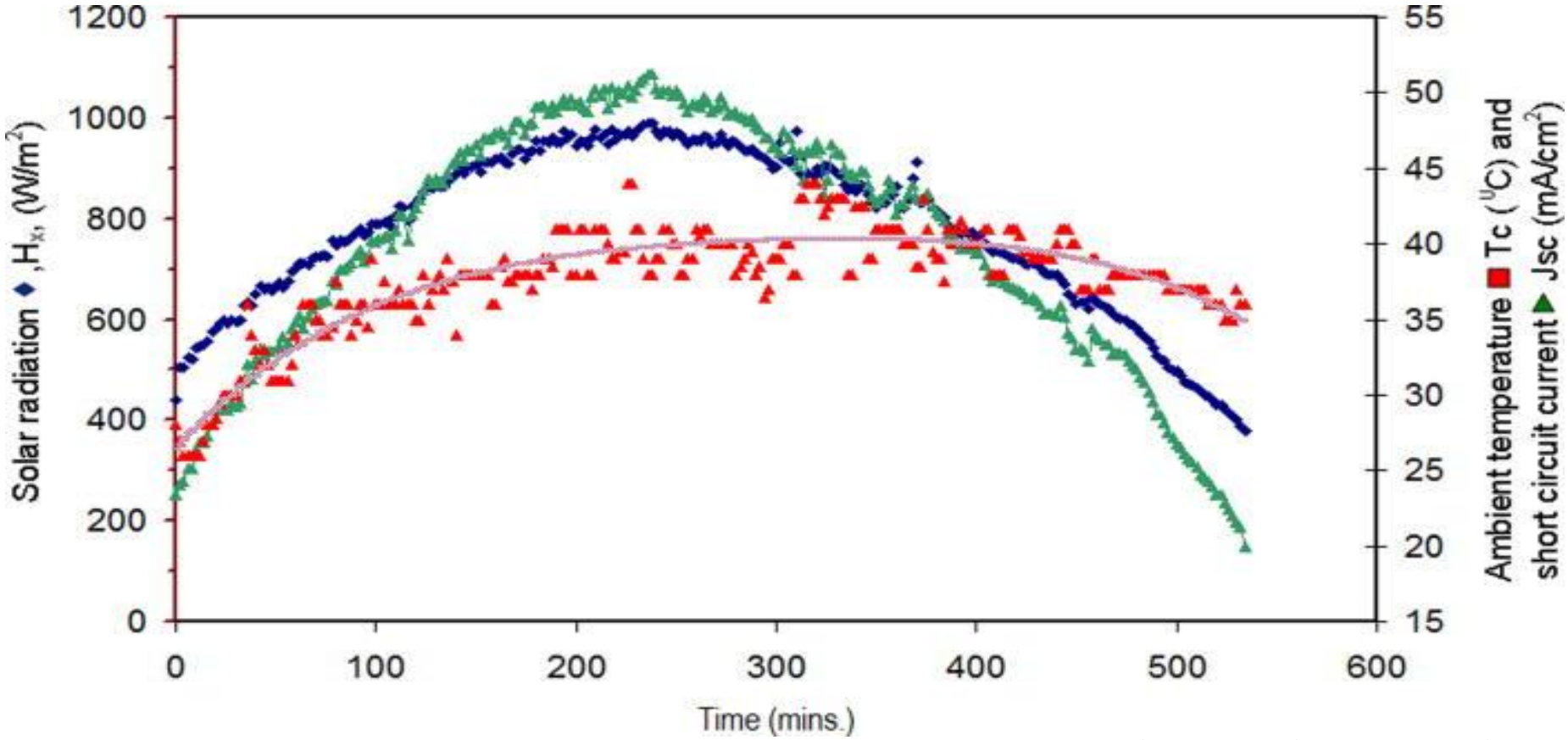


Global Sunlight

- The cells to be calibrated and a pyranometer are placed on a horizontal surface.

- The calibration site environmental conditions need to fulfil several requirements relating to global and diffuse irradiance levels, solar elevation, unobstructed view over a full hemisphere.

- **The solar cells calibration under global solar radiation**



Direct Sunlight

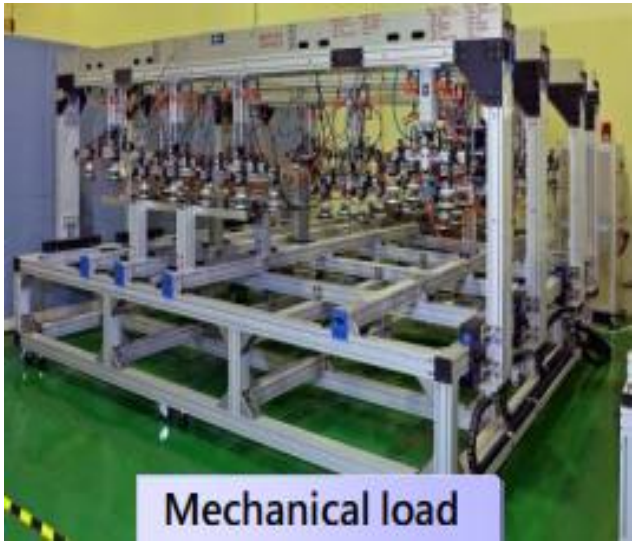
- The cells to be calibrated are placed on the bottom plate of a collimation tube.
- a normal incidence pyrheliometer and a spectroradiometer are kept pointing to direct sunlight while measurements of short-circuit current, total irradiance and spectral irradiance are recorded.
- Several conditions need to be fulfilled by the calibration site and its environment EX (certain irradiance level, stable cell short-circuit readings, and ratio of diffuse to direct irradiance).

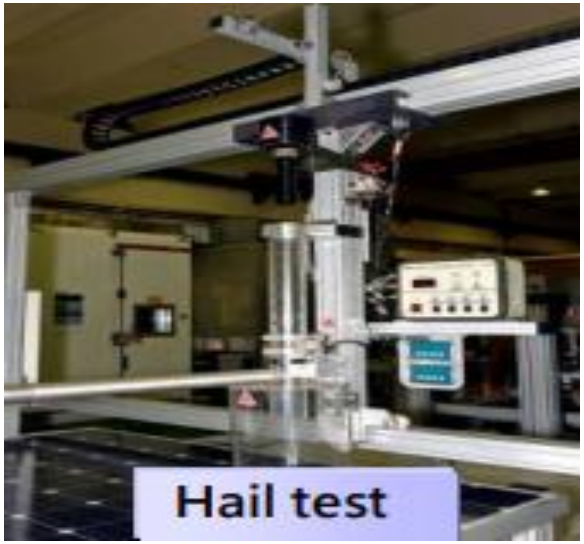
Testing

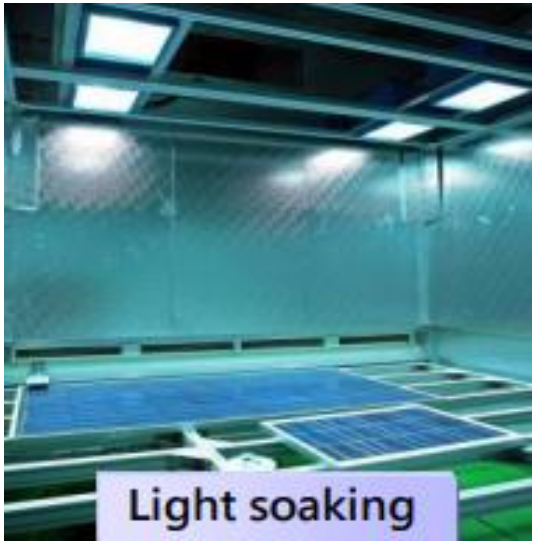
Solar Module Model Pass-Fail Qualification

- The specific series of test are specified in standards of the **IEC**
  * IEC Standard 61215 (modules with silicon crystalline cells).
  * IEC Standard 61646 (modules with thin-film cells).
- These two **IEC** standards reference several other related IEC standards:

- PV module manufacturers voluntarily conduct these series of tests.
- Testing only conducted on new modules.
- Modules are labeled to confirm passing the applicable suite of **IEC** qualification tests.
- Although sometimes used to infer module lifetime, not designed to do so; alternative ways being developed to perform accelerated aging testing







PV System monitoring

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PV system monitoring

- Monitoring and control of photovoltaic systems is essential for reliable functioning and maximum yield of any solar electric system.
- The simplest monitoring of an inverter can be performed by reading values on display.
- Values like PV array power, AC grid power, PV array current are usually available.
- For sophisticated monitoring and control purposes environmental data like module temperature, ambient temperature, solar radiation, wind speed can also be data logged, stored and analysed later.

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1. **Local Monitoring**

- Most simple way to perform local monitoring is display available on inverter or on inverter control unit.
- Other possibilities of local monitoring includes monitoring by local PC via RS232 connection and/or remote display located in living room for example (connection between inverter and display is usually wireless).
- The following parameters can usually be monitored, datalogged and stored in inverter's memory or external data logger for particular time.

Parameters	#	Unit
Array voltage	V_{DC}	V
Grid voltage	V_{AC}	V
Array current	I_{DC}	A
Grid current	I_{AC}	A
Array power	P_{DC}	W
Grid power	P_{AC}	W

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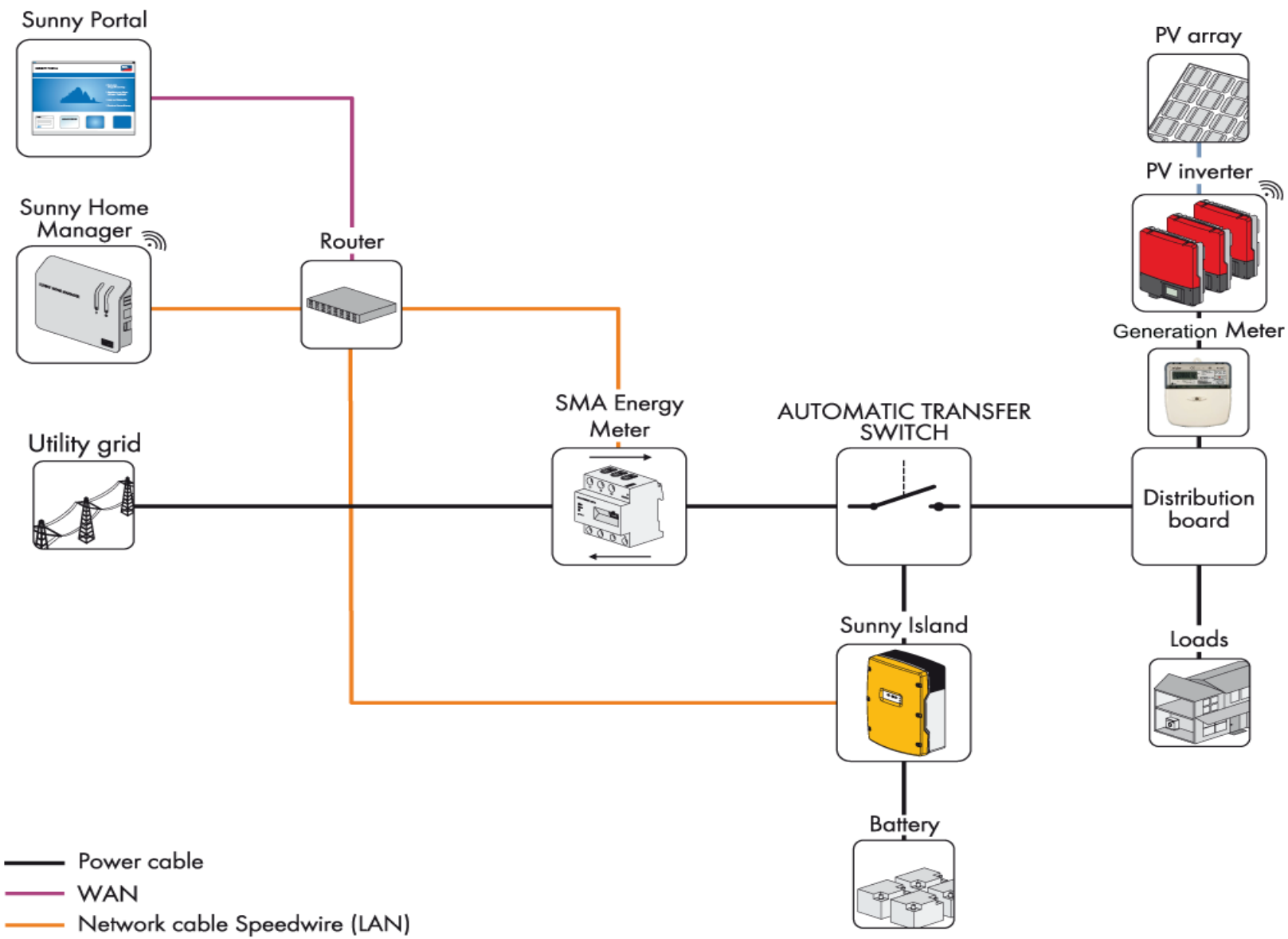
2. **Remote monitoring**

- Remote control and communication between inverters can be realized with wireless connection (Bluetooth or Wi-Fi), trough RS485 interface or via grid (powerline connection).
- Distances up to 1200 m represents no problem, several tenth inverters can be connected in chain and monitored at the same time.
- For remote monitoring different ways of communication can be used: Ethernet, Internet, dial up access.
- System can send alerts and status messages to the control center or user.
- Alerts and system messages can be send by SMS service, fax machine.



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