Introduction to Solar Radiation

Fundamentals of PV Engineering

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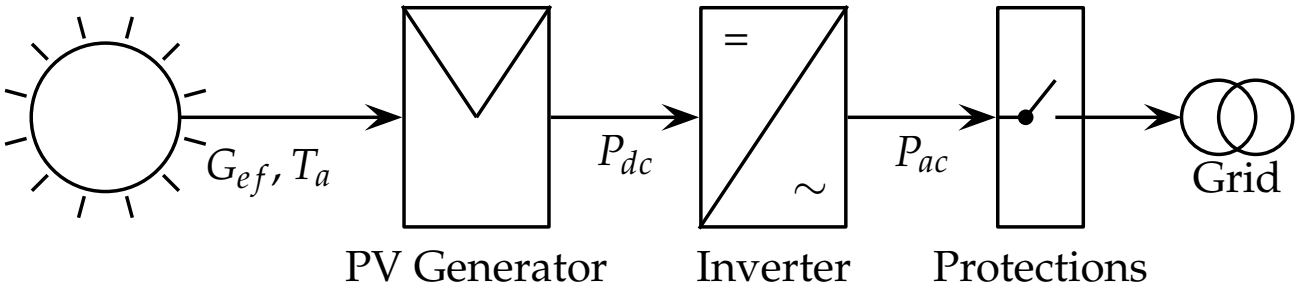
Motivation

Key concepts

Definitions

Radiation and PV Systems

- The energy produced by a PV system depends mainly on the solar radiation incident on the PV generator.
- Consequently, the estimation of performance of a PV system in a location during a time period requires the knowledge of the available solar radiation.



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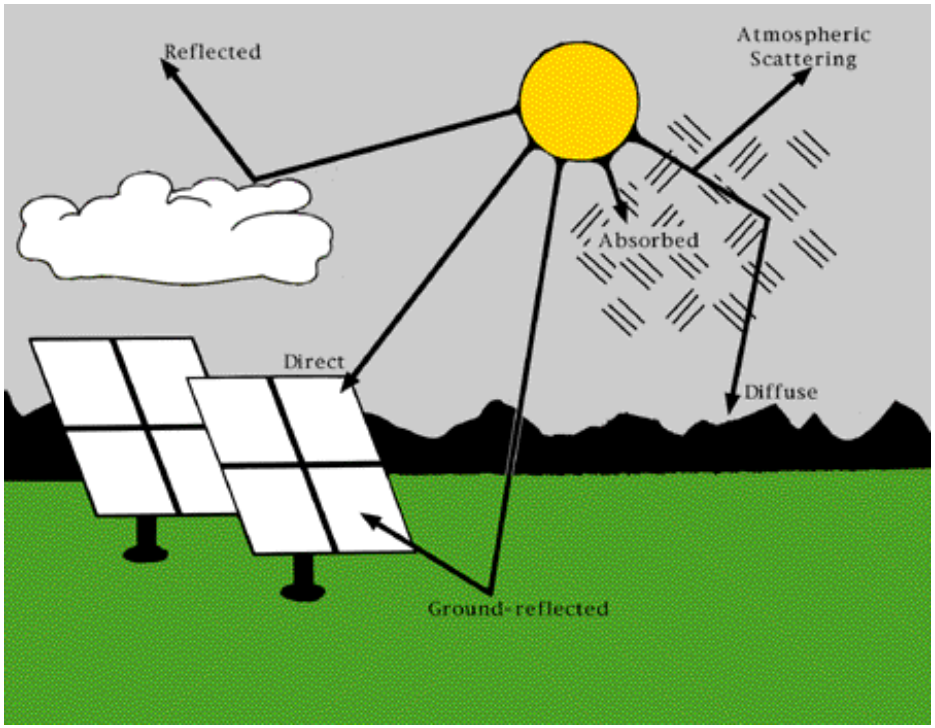
Solar Radiation cannot be computed

- Solar radiation reaching the earth surface is the result of **complex interactions with the atmosphere**.
- On-site measurements or satellite images are required for solar radiation estimation.



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Inclination Angle

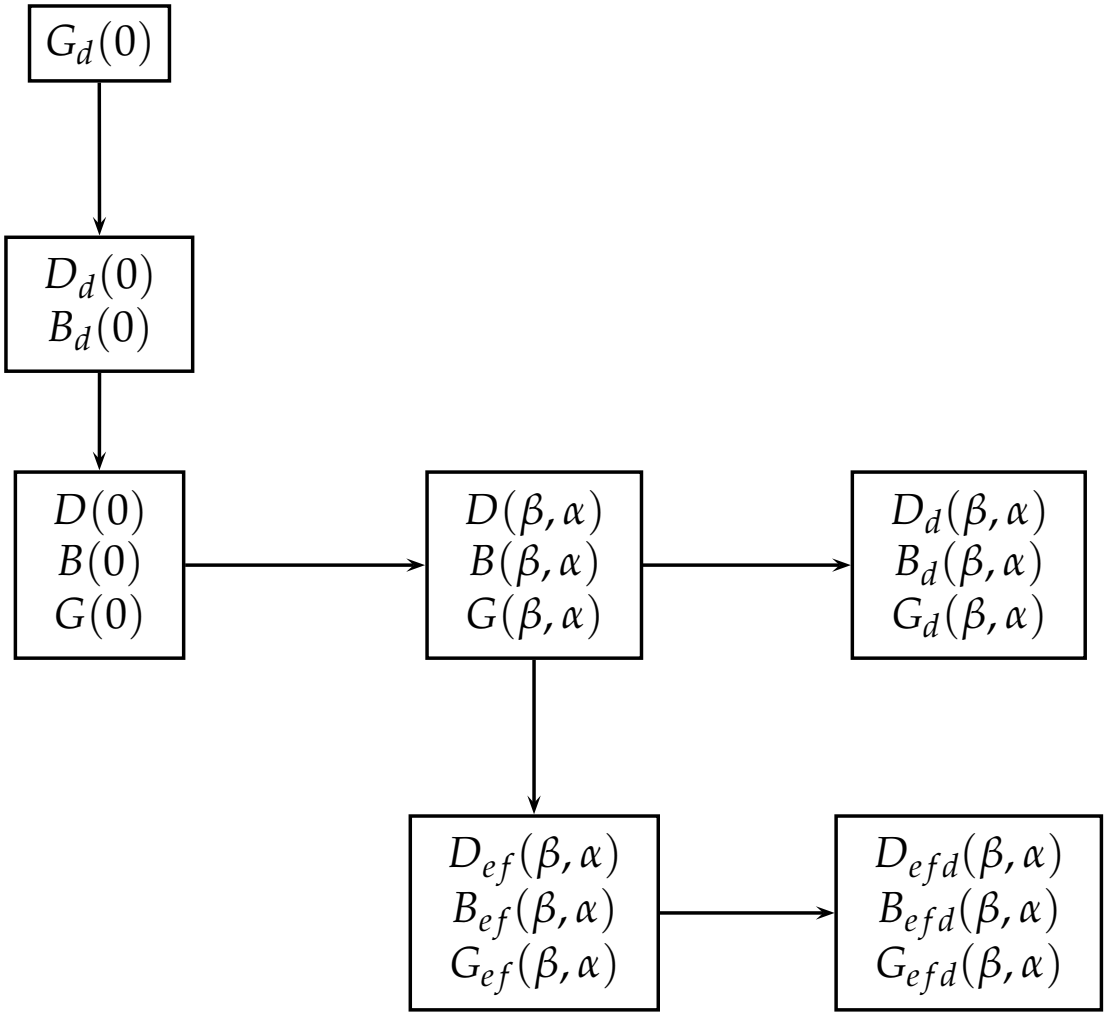
- PV generators have an **inclination angle higher than zero** to maximize the performance.
- The generator inclination angle depends on the latitude of the location and on the application*.

*Rule of thumb: latitude minus 10º for a Grid Connected PV System; latitude plus 10º for a Standalone PV System.

Solar Radiation Databases

- Therefore, it is unfeasible to maintain a database of incident solar radiation.
- Databases register solar radiation on the horizontal plane.
- Estimation of the solar irradiation **incident on the inclined plane** requires a transposition procedure.

From Horizontal to Inclined



Motivation

Key concepts

Definitions

Irradiance and Irradiation

Irradiance solar radiation **power** received by a surface per unit area.

- Units: $\mathrm{W\,m^{-2}}$, $\mathrm{kW\,m^{-2}}$

Irradiation solar radiation **energy** received by a surface per unit area.

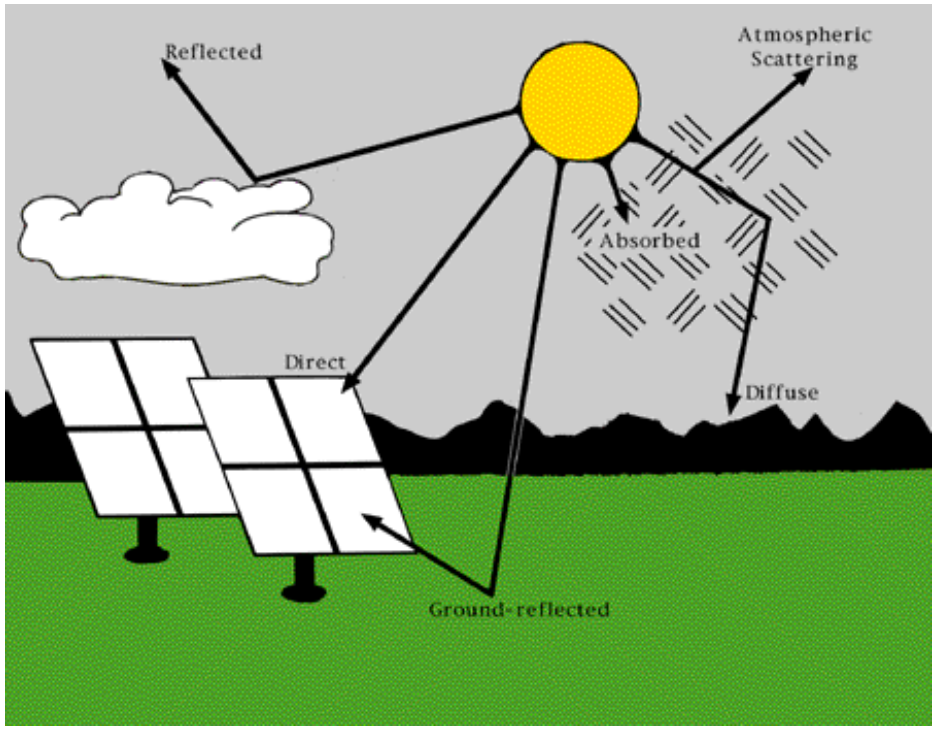
- Units: $\mathrm{Wh\,m^{-2}}$, $\mathrm{kWh\,m^{-2}}$
- Hourly irradiation, Daily irradiation, Monthly irradiation ...

Extraterrestrial Solar Radiation

- B_0: Solar radiation energy/power at the top of the Earth's atmosphere on a surface perpendicular to the solar rays.
- $B_0 \simeq 1367\,\mathrm{W\,m^{-2}}$ (Solar Constant)
- $B_0(0)$, extraterrestrial irradiance on a horizontal plane, can be computed by analytical means.
  - Depends on the latitude, day of the year, hour of the day.

Interaction with the Atmosphere

Due to the interaction with the atmosphere, the extraterrestrial radiation is absorbed, reflected and scattered.



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Diffuse, Beam, and Global

- Solar radiation reaching the Earth surface is named **global solar radiation**.
- It is the result of three components:
  - **Beam Radiation**: solar radiation traveling on a straight line from the sun to the receiving surface.
  - **Diffuse Radiation**: solar radiation scattered by the atmosphere. It is emitted from all directions of the sky.
  - **Albedo or Reflected Radiation**: solar radiation reflected by the ground.

$$G = B + D + R$$

Horizontal, Incident, Effective

- $G(0)$ **Radiation on a Horizontal Plane**
  - Measurements from ground stations, or satellite images.
- $G(\alpha, \beta)$ **Radiation incident on an Inclined Plane**
  - Transposition from radiation on the horizontal plane.
- $G_{ef}(\alpha, \beta)$ **Effective Radiation incident on a PV module**
  - Reflectance and transmittance of the PV module depend on the angle of incidence.
  - Dirt losses.