Quick Reference Guide of MeanPTC Software

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1. Scope

The software MeanPTC is a tool for computing the frequency distribution of the incidence angle on the mirrors composing a given solar linear collector, parabolic-trough or linear Fresnel, as well as the frequency distribution of the (half) acceptance angle of the receiver viewed by each point of reflection in the direction of the reflected ray.

2. The software

MeanPTC is C++ written and provided with a Graphical User Interface (GUI) based on the Qt library; the frequency distribution graphs of incidence and acceptance angle are drawn by means of the Qwt library.

MeanPTC is an open-source software distributed under the GNU General Public License as published by the Free Software Foundation version 3. MeanPTC can be downloaded from the web site *Italian Solar Radiation ATLAS*, http://www.solaritaly.enea.it/StrMeanPTC/MeanPTCEn.php

3. Installation

The first two steps are:

1) download the zipped file from http://www.solaritaly.enea.it/StrMeanPTC/MeanPTCEn.php
2) extract the folder `Export_MeanPTC` to the wished position on the user hard disk,

therein the user will find the present quick guide, the `bat` file to launch the Windows executable and the folder `Workspace`, which is a structured work directory containing source files, Windows executable, and several DNI data files. As later explained, the user is allowed to enrich the `DNIdata` folder with his own DNI data file according to the format of the distributed exemplary files.

To compile the source files in Linux:

- install the libraries: Qt and Qwt
- open a terminal and change directory to the folder containing the source files
- compile the project with the command "qmake"
- complete with the command "make"
- alternatively, launch the QtCreator application, open the project file `MeanPTC.pro`, configure the project as required, and compile by pushing the dedicated button.

For Windows users:

- double-click on the launcher `MeanPTC_WinExecLauncher.bat`

Please test the good working, by selecting one of the predefined sites and then pushing the button “Load Yearly Data and Compute”; two new windows with the frequency distribution graphs will pop-up and mean and standard deviation values will be displayed in the bottom of the GUI.

4. Usage

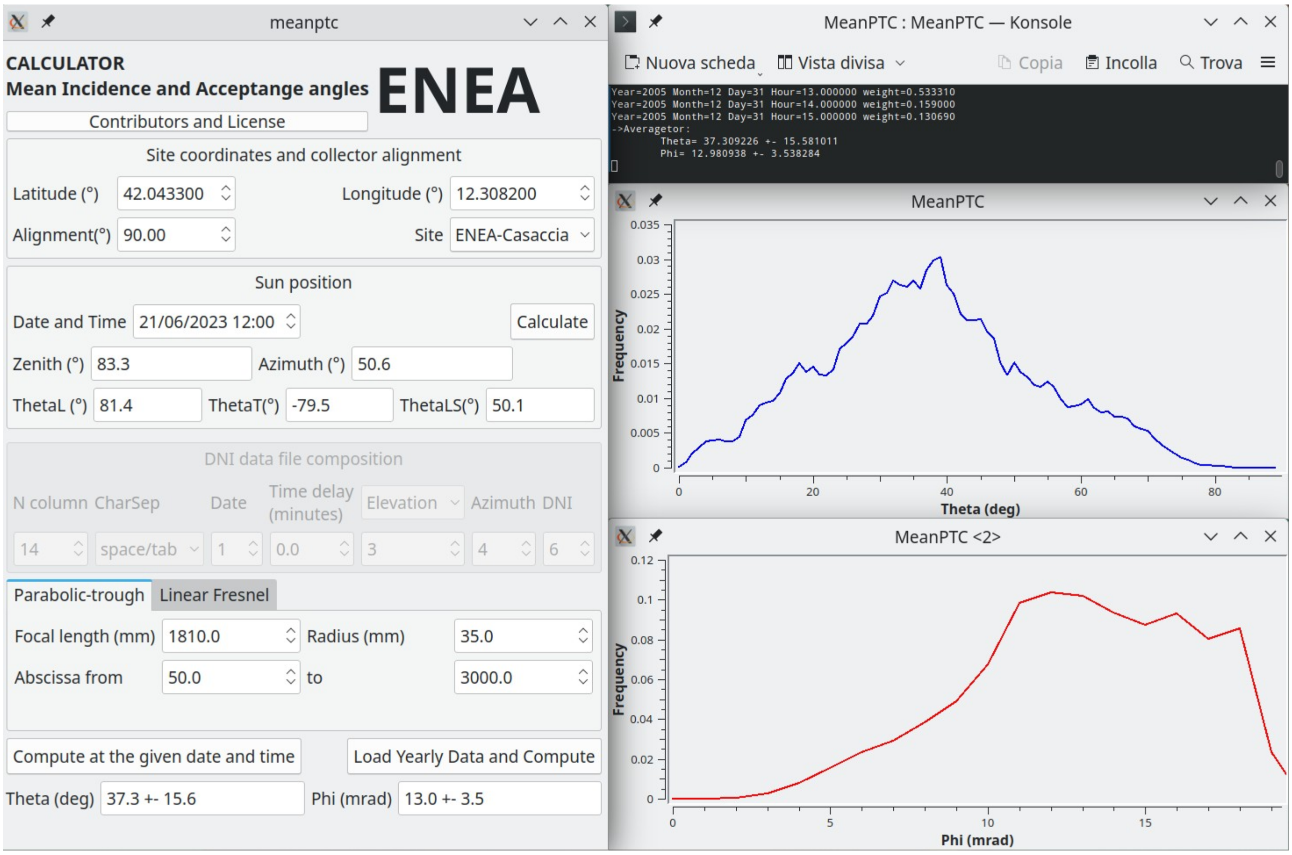

Fig. 4.1: MeanPTC software: on the left the GUI; on the right, terminal (top), and graphs of frequency distribution of incidence (Theta) and (half) acceptance angle (Phi).

The GUI is organized in several group-boxes. In the one on the top, the user has to set Latitude and Longitude (deg) of the site of interest, as well as the orientation angle made by the linear-collector axis with the North direction (0° for North-South, 45° NE-SW, 90° for East-West orientation, ...).

The last element of the “Site coordinates and collector alignment” group-box is a pop-up menu where the user can select one among the several sites already recorded at the file

```
~Workspace/qtSource/MeanPTC/SiteCoord.xt
```

Here each site is described by 3 rows, respectively containing: the label to be displayed in the menu, Latitude and Longitude (deg), followed by the delay (minutes) between DNI and time. As an example:

```
ENEA-Casaccia
42.0433 12.3082 0.
DNI_ENEAcas.txt
```

The user is allowed to edit this file, but he must respect the above format; at the same time he has to arrange a file composed by 3 columns: data, time and DNI, spaced by blank or tab; this file has to be added to the folder `~Workspace/DNIdata`

When one of the recorded sites is selected, the user can push the “Load Yearly Data and Compute” button to launch the computing of the distribution frequency. The user can check the progress by looking to the messages displayed in the terminal window; at the end two new graphs showing the frequency distribution will pop-up.

Differently, when the menu is set to “Custom”, at the pushing of “Load Yearly Data and Compute” button, the user will be asked to select a valid DNI file, which structure must be preliminary specified in the group-box “DNI data file composition”; in particular the separation character and Elevation/Zenith option must be set; the value of the solar angles must be in degrees; the time column is assumed to be the next on the right of the date column. Please note that this group-box is enabled only when the “Custom” option is selected.

If the user set to 0 the number of the column listing Elevation/Zenith and Azimuth, the software will evaluate Zenith and Azimuth by the Algorithm3 described Roberto Grena in the paper "Five new algorithms for the computation of sun position from 2010 to 2110", Solar Energy 86 (2012) 1323-1337; the maximum error of Algorithm3 is 0.0094 deg.

The same algorithm is used in the computing when one of the already recorded sites is selected.

The computing is dealt according to the kind of solar collector specified in the bottom group-box, which is organized in two separate Tabs, “Parabolic-trough” and “Linear Fresnel”; here the user has to set the main parameter of the collector of interest.

In the case of parabolic-trough collector, due to the specular symmetry of the reflector, the computing can be limited to half parabola; the user has to set the abscissa range of the half parabola.

In the case of Linear Fresnel, thanks to the low curvature of mirrors, the computing can be limited to the central point of the mirror row.

As final feature, in the “Sun position” group-box the user can launch the Algorithm3 to evaluate Zenith and Azimuth at a given date and time for the site already specified in the “Site coordinates and collector alignment” group-box. The user can include the computing of incidence and acceptance distribution limited to that time and date by pressing the button “Compute at the given date and time”.

A1. Incidence Angles for Linear Collectors

Let XYZ a reference frame with: Z axis aligned along the vertical; Y axis parallel to the linear receiver, pointing to North when the collector is N-S aligned; origin in the middle of the primary mirror width, i.e. along the vertical projection of the receiver.

Let Zen and Azi respectively Zenith and Azimuth of the Sun; the Azimuth is 0° at noon, gets negative values in the morning, and positive values in the afternoon.

In the reference XYZ, the unit vector aiming to center of the Sun has components

$$\vec{u_S} = [-\sin Zen \ \sin(Azi - O)\,, \ -\sin Zen \ \cos(Azi - O)\,, \ \cos Zen]$$

where O is the orientation angle of the linear collector with respect to the North direction.

Transversal, longitudinal and longitudinal solar incidence angles (see Fig A1.1) are given by the equations

$$\theta_T = \arctan(\sin(Azi - O) \ \tan Zen)$$
$$\theta_L = \arctan(\cos(Azi - O) \ \tan Zen)$$
$$\theta_{LS} = \arcsin(\cos(Azi - O) \ \sin Zen)$$

where θ_T is oppositely signed to its projection on X axis.

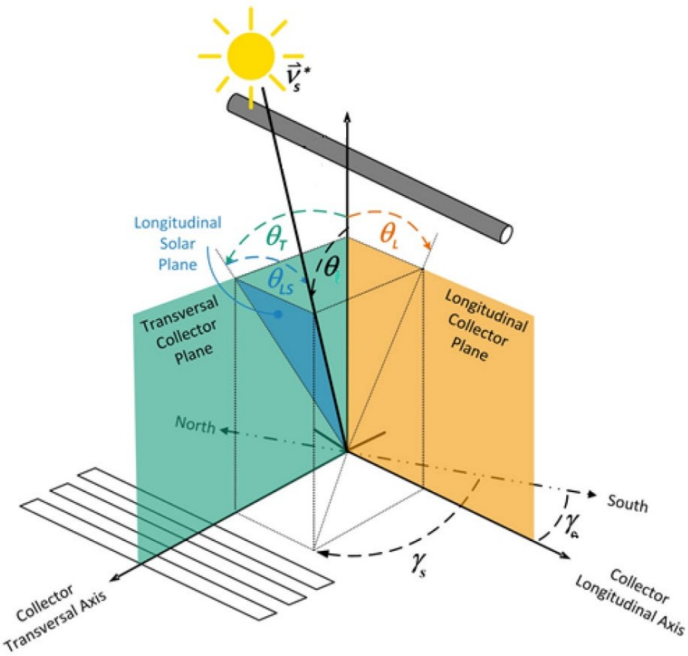

Fig. A1.1: Incidence angles for a Linear Fresnel Collector:
θ_L projection of the zenithal angle on the longitudinal collector plane,
θ_{LS} projection of the zenithal angle on the longitudinal solar plane,
θ_T projection of the zenithal angle on the transversal collector plane.
Source: IEC Solar thermal electric plants – Part 5-2: System and components – General requirements and tests methods for large-size linear Fresnel collectors (draft).

A2. Parabolic-trough collectors

Let XYZ a reference frame with origin in the parabola vertex and oriented so that the ideal parabolic profile is given by the equation

$$z = \frac{1}{4f}x^2$$

where f is the focal length of the parabola.

In tracking condition, let θ_{LS} the longitudinal incidence angle of the solar radiation with the aperture area of the collector.

In the generic point of the reflective parabolic surface $P = \left(x, y, \frac{1}{4f}x^2\right)$ the unit vector aiming to the center of the Sun has components

$$\vec{u_S} = (0, -\sin\theta_{LS}, \cos\theta_{LS})$$

In the same point, the unit vector aligned to the normal to the surface has components

$$\vec{n} = (-\sin\alpha, 0, \cos\alpha)$$

where $\tan\alpha = \frac{1}{2f}x$.

The angle between the two unit vectors $\vec{u_S}$ and $\vec{n}$ is the incidence angle θ of the solar radiation in the point *P* of the parabolic surface. Thanks to the scalar product,

$$\cos\theta = \vec{u_S} \cdot \vec{n} = \cos\theta_{LS}\ \cos\alpha$$

Let $\vec{u_R}$ the unit vector aligned with the reflected ray. On the basis of the reflection laws,

$$\vec{n} = \frac{\vec{u_S} + \vec{u_R}}{2\cos\theta}$$

thus

$$\vec{u_R} = 2\cos\theta\ \vec{n} - \vec{u_S} = (-2\cos\theta\ \sin\alpha,\ \sin\theta_{LS},\ 2\cos\theta\ \cos\alpha\ - \cos\theta_{LS}).$$

From *P* the path length t along the reflected ray to its intersection with the focal line is given by

$$t = \frac{f - \frac{1}{4f}x^2}{2\cos\theta\ cos\alpha - \cos\theta_{LS}}$$

Therefore, from P the (half) acceptance angle of the receiver

$$\varphi = \frac{1}{2}\frac{\varnothing}{t}$$

To study the yearly behavior of incidence and acceptance angle, their instantaneous values have to be weighted by the factor

$$DNI\ \cos\theta_{LS},$$

where DNI is the direct normal irradiation and the term $\cos\theta_{LS}$ take into account the effective area intercepting the solar radiation.

A3. Linear Fresnel collectors

Let x the abscissa of one of the primary mirror rows and h the height of the aperture plane of the receiver from the primary mirror plane; the angle made by the vertical and the straight line crossing incidence point and center of the receiver-aperture is $\alpha = \arctan \frac{x}{h}$, signed oppositely to its projection on X axis.

In order to reflect the incoming radiation towards the center of the receiver aperture, the mirror must be oriented in such a way that the angle made by its normal and the vertical is

$$\beta = \theta_T - \frac{\theta_T - \alpha}{2}$$

where θ_T is the transversal angle of the solar radiation with the linear collector.

The unit vector normal to the mirror surface is

$$\vec{n} = (-\sin\beta, 0, \cos\beta)$$

The incidence angle of the solar radiation with the mirror surface can be obtained by the scalar product

$$\cos\theta = \vec{u_S} \cdot \vec{n}$$

The path length t to the center of the receiver aperture is

$$t = \frac{\sqrt{x^2 + h^2}}{\cos\theta_{LS}}$$

The acceptance angle of the receiver aperture is

$$\varphi = \frac{1}{2} \frac{W \cos\alpha}{t}$$

To study the yearly behavior of incidence and acceptance angle, their instantaneous values have to be weighted by the factor

$$DNI \ \cos\theta,$$

where DNI is the direct normal irradiation and the term $\cos\theta$ take into account the effective area of the considered mirror row intercepting the solar radiation.