SolarFarm

User Guide

Version 2.0
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SolarFarm uses the GLScene Open Source code, an OpenGL based 3D graphic library for Delphi. GLScene is currently distributed under Mozilla Public License. More info: www.glscene.org

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1   Before you Begin

1.1   About SolarFarm

SolarFarm provides 3D graphic interface tools for analyzing and optimizing photovoltaic power plants designed with ADES solar trackers. Optimization process consists in obtaining the best energy production vs. field surface ratio for any arbitrary site topography.

Installation requirements:

- The *SF_install.exe* file, including the following files:

    - *Solarfarm.exe* (program executable file)
    - VLC libraries
    - Sample solarfarm files (**.sff*)
    - Terrain sample dxf file (*terrain 1.dxf*)
    - *User guide.pdf* (this file).

- A computer running Windows Vista, XP or 2000 with at least 100Mb of free disk space.

- A graphic card with OPENGL graphics acceleration feature is recommended.

SolarFarm combines an hourly simulation model of terrain shading due to ADES trackers and existing buildings with self interference analysis of solar beam rays between different trackers and buildings.

Program inputs are:

    - Terrain geometry
    - Site latitude
    - Tracker model
    - Photovoltaic plant layout (incl. trackers and buildings)

1.2   About this guide

This user guide describes the current version of the SolarFarm software. The guide introduces new users to the software and describes basic tasks required to review a complete analysis or to perform a new analysis.

- The Getting Started and User Interface Overview chapters explain how to install SolarFarm and introduce you to the software.

- The Guided Examples explains some cases and discussion of results.

> **Note:** The images of the SolarFarm user interface in this guide may have been prepared using different files that the ones you are reviewing. Some of the images may not exactly match what you see on your screen.

1.3 Contacting user support

If you have any questions about SolarFarm or this guide, please send an email to ades@ades.tv.

SolarFarm is under continuous development. Please visit the ADES webpage to check if new versions of SolarFarm software and manuals are ready for downloading.

2 Getting Started

2.1 Installing and starting the software

The following procedure describes how to install the software, open a sample file and create a second copy of the file for modifying. SolarFarm comes with a set of two sample files:

  o *Example 1.sff*
  o *Example 2.sff*

The samples files are allocated in the *Samples* folder. The *Samples* folder is located in the same folder as the SolarFarm program files, which is C:\SOLARFARM by default, unless you specify a different folder in the installation process.

> **Note:** SolarFarm must be installed on a local drive. The software will not work properly if it is installed on a network disk or if any of the files it uses are on a network drive.

To install SolarFarm and start the software

1. Download or copy the installation file, *SF_install.exe*, to a convenient folder on your computer. You can download the file from www.ades.tv

2. Run the installation file and follow the installation wizard instructions

3. On the Windows taskbar, click the start button

4. Click *All Programs*, and click ADES/*SOLARFARM/Solarfarm* to start the software. There are several ways to start the software. For example, depending on your Windows setup, you can click the shortcut on your desktop (if you created during the installation process), or the command in the Start menu.

To uninstall SolarFarm

1. On the Windows taskbar, click the start button

2. Click *All Programs*, and click ADES/*SOLARFARM/Uninstall* to remove the software from your computer.

2.2   What to do if you encounter a bug

SolarFarm is under development and may occasionally fail. If you encounter a bug while using the software, SOLARFARM displays error messages. In that case, accept the message, save your work and continue with the application. If the message persists, close the program and restart it. We will appreciate if you please contact the User Support to let us know how the bug occurred.
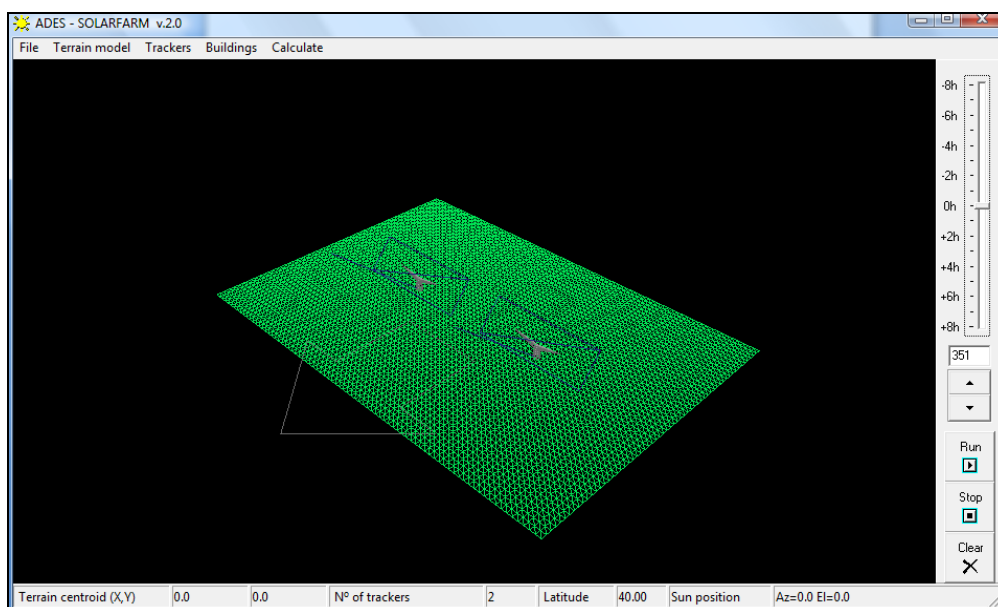
2.3   Opening an existing file

Once you start SolarFarm, the following main window appears:
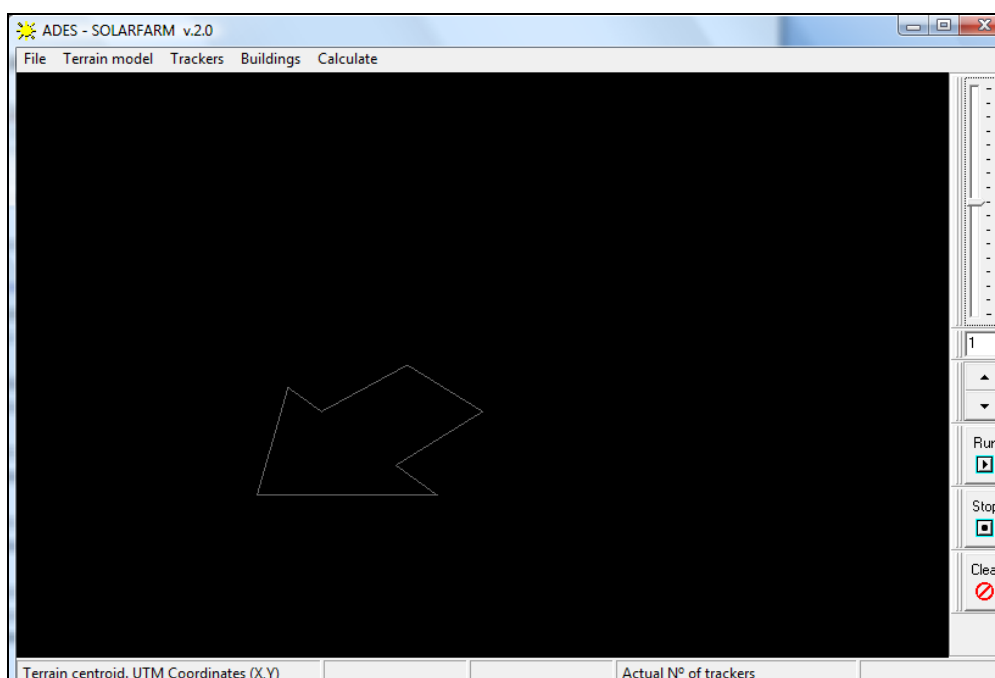
To open an existing file, click on the *File/Open* menu. Try to open the file named "*Example 1.sff*", in the *Samples* directory
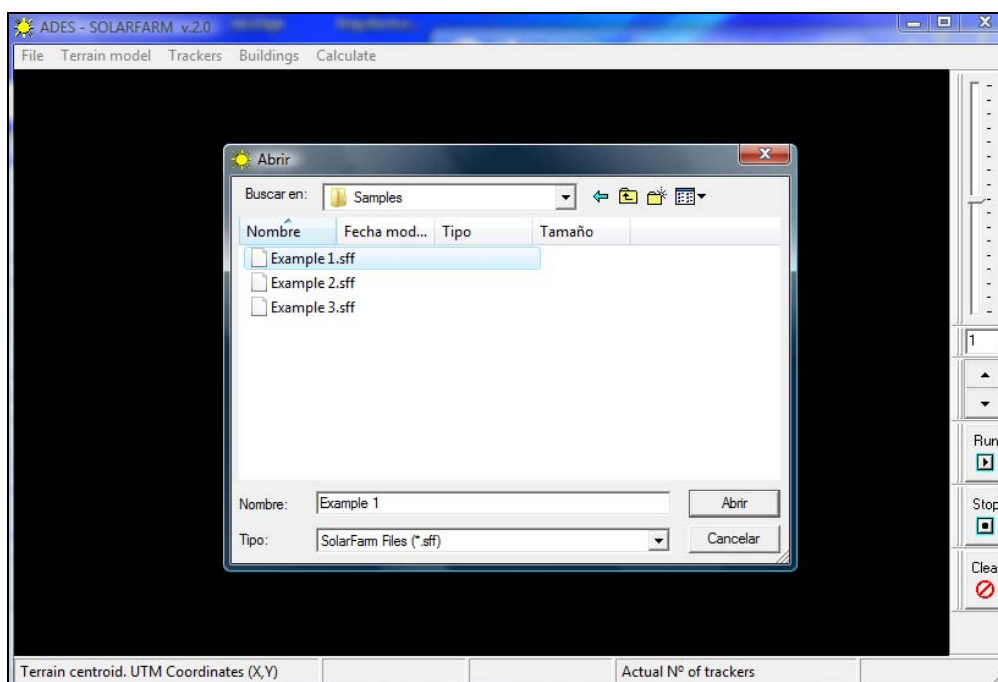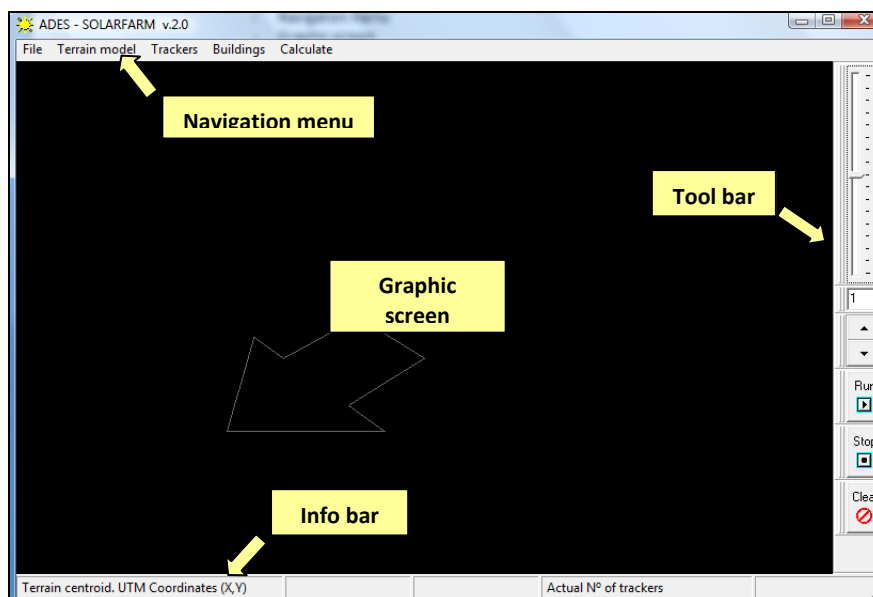

Then following case is shown:

To create a copy of this file, click on *File/Save* menu and give the case a new file name.

# 3   User Interface Overview

3.1   Main window

3.1.1   The graphic screen

The black background graphic screen displays permanently a white arrow pointing to the geographic South (the south-arrow).

- To Zoom-in or Zoom-out the 3D view in the graphic screen just left click-and-drag on the graphic screen while pressing the Shift-Key.

- To rotate the 3D view in the graphic screen just left click-and-drag on the graphic screen while pressing the Ctrl-Key. 3D view rotations are always around the screen midpoint.
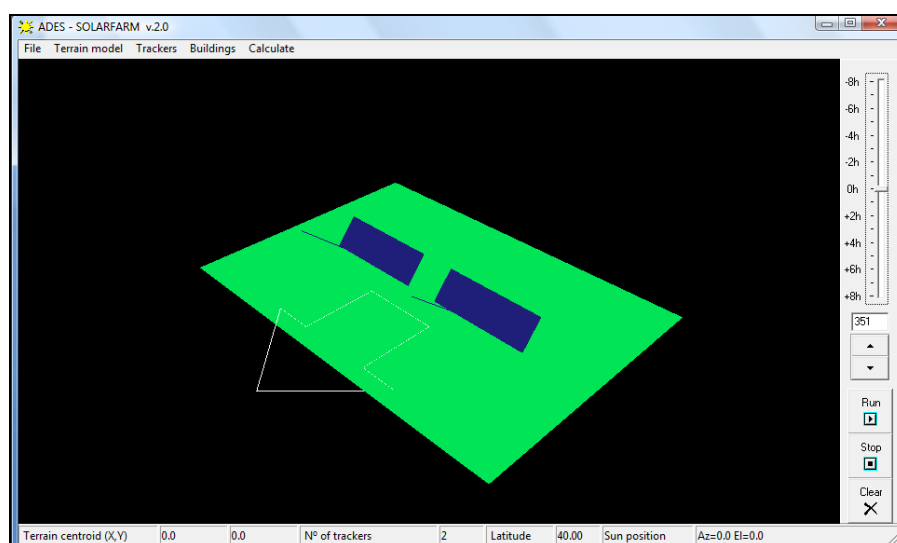
Try the above to check how the scene of "*Example 1*" behaves, so to get familiar with the 3D displaying operations.

Geometry is shown with a "wireframe" aspect. You can switch to a "solid" aspect by clicking on the mouse middle button, or by selecting the *Terrain model/View/Solid* menu:
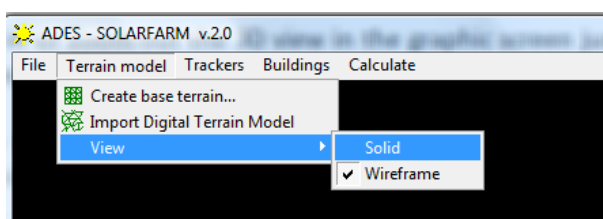
The solid aspect is as shown below:


3.1.2 The navigation menu

The navigation menu consists of five main items:

- File   Performs file management (Open, Save, Print and Exit)
- Terrain model   Performs terrain model operations (Create, Import)
- Trackers   Select type and position of ADES trackers over terrain
- Buildings   Define size and position of buildings over terrain
- Calculate   Select the type of analysis to perform (Shading, Interferences)

3.1.3 The Tool bar

The tool bar allows the user to select the hour, and the day of the year to analyze.

The hour of the day varies from -8h to +8h, being the 0h the midday (i.e. sun at south). You can change the hour of the day by moving the vertical slider position. Time resolution is half-hour.

-8h : Morning

0h : Midday

+8h : Afternoon
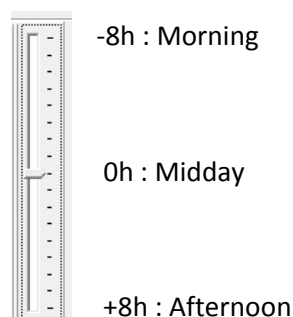
Tip: If your mouse has a wheel, it is normally easier to change the slider position by moving the mouse wheel, after left-clicking on the slider. Alternatively, you can use the keyboard arrows or the RePag, Avpag keys.

The day of the year varies from the winter solstice (day 351, i.e. December, 21st) to summer solstice (day 171, i.e. June,21st) following the Julian convention (i.e. January, 1st being the day number 1). Other days out of the interval [351..171] are irrelevant since sun path is identical with respect to the corresponding symmetric Julian day (i.e., day 172 is identical to day 170).

You can change the day of the year by editing the text box under the hour slider or by increasing/decreasing the value with the Up/Down arrow buttons.

Julian day of the year (edit box)

Up/Down buttons

A complete year can be analyzed by just clicking on the "Run" button. A Run can be stopped at any time with the "Stop" button.

Terrain calculated shades can be erased with the "Clear" button at any time.

Run: Yearly analysis

Stop: Abort Run

Clear shadowing results

> **Note:** When launching a complete year analysis check that the day edit box shows day number 351 (i.e. December, 21st). Otherwise the calculation will cover from the appearing day up to day number 171 (June, 21st)

3.1.4 The info bar

The info bar is located at the bottom of the graphic screen, and gives some useful indications:

- Absolute coordinates of the terrain midpoint
- Actual number of trackers
- Site latitude
- Sun azimuth and elevation angles

3.2   Shading calculations

Once the case is loaded, calculating terrain shades due to trackers is straightforward: Select the *Calculate* menu. The following dialog appears:
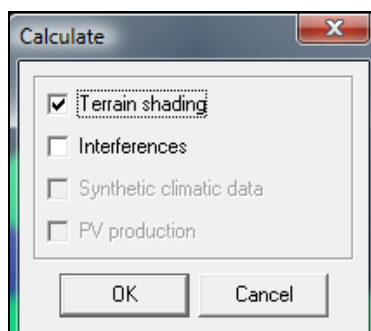

Select "*Terrain Shading*" and accept.

Now you can change the hour of the day by changing the slide position and check the shadows for the selected day at the input hour
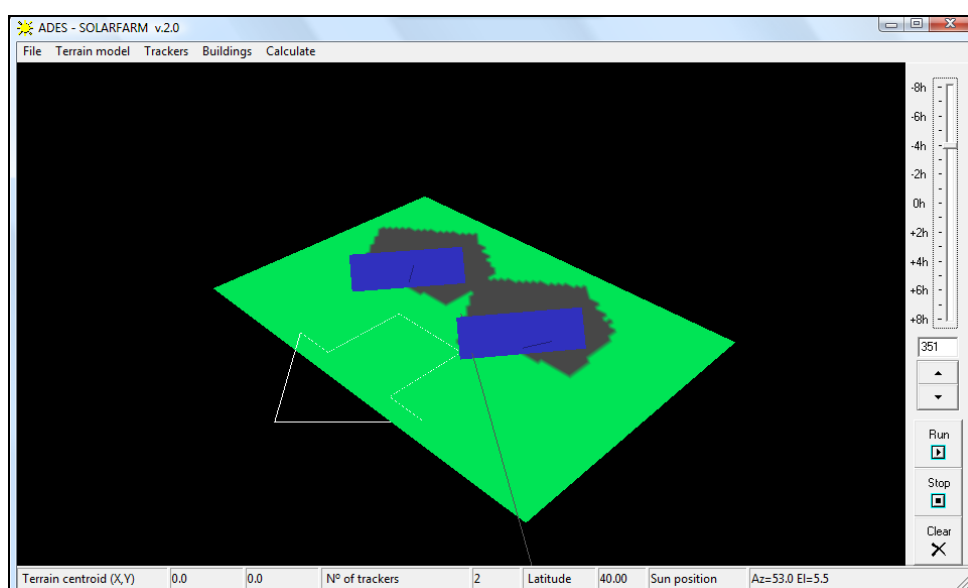

The yellow line represents a solar beam, therefore pointing to the instantaneous sun position.

Change the day of the year and proceed as before to produce the shadows. You can always clear the results by clicking on the "Clear" button, or perform a complete year analysis to obtain the full shading map (remember to set the first day as day № 351)
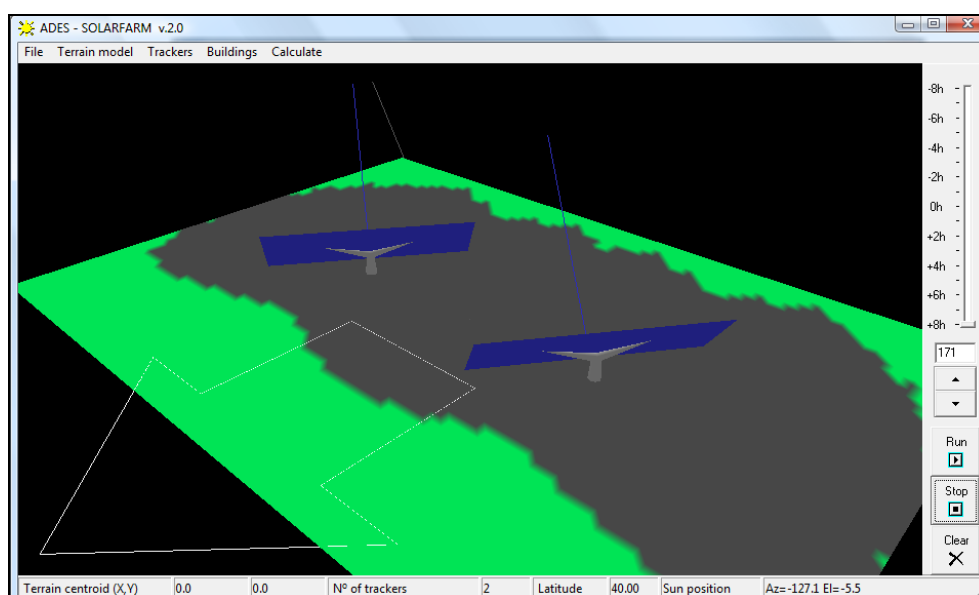
3.3   Measuring & printing shadows

Click on the *File/Print* menu to open the measuring/print utility. The following new window will open, with a bird-view of the case
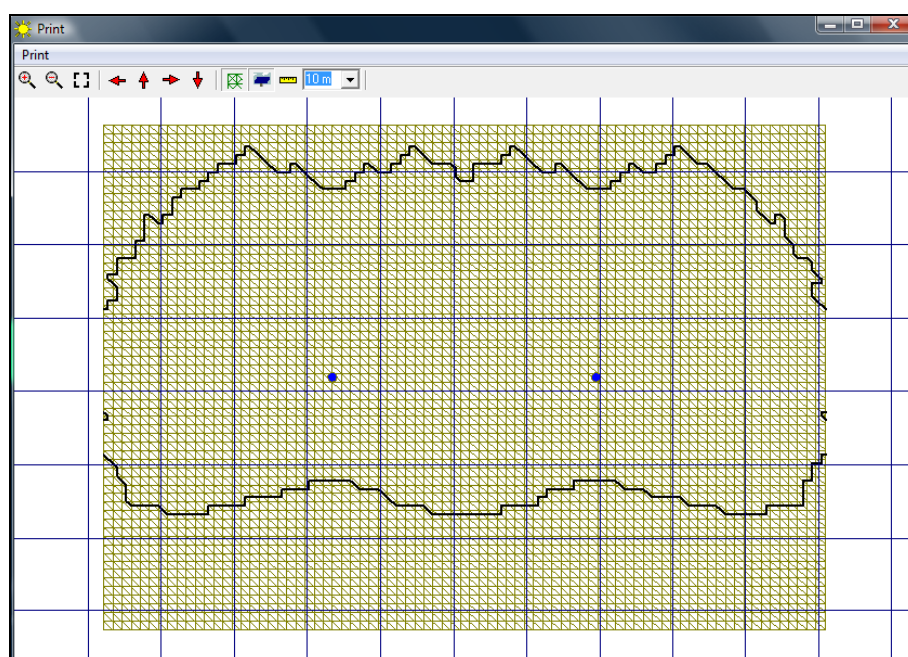
The tool bar buttons are as follows:

Zoom buttons

   Zoom-In / Zoom-out / Zoom-All the 2D image.

Move buttons

 Allows moving the 2D image around.

> **Tip:** Displacement of the 2D view can also be done by click-and-drag the mouse left button on the screen.

Show/Hide buttons

 Allows hiding the terrain mesh, shading and measuring grid pattern. The measuring grid scale can be changed to the following units: 10m grid, 5m grid and 1m grid.

Moving the 2D image over the fixed measuring grid permits to measure distances and shadows sizes.

To send the 2D image to your favourite printer, click on the *Print* menu item.

Close the Print window to go back to SOLARFARM main window.

3.4   Interference analysis

Shading calculations might be time-consuming if the case is complex (i.e., high number of trackers). In fact, what is really important for PV plant design is the interference analysis rather than terrain shading (this will be discussed in detail in further chapters in this guide).

3.4.1   Detecting interferences

To perform an interference analysis, click on the *Calculate* menu item and choose the "*Interferences*" option this time
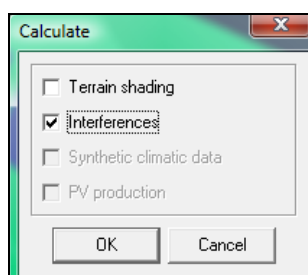

Now, as we did for the shading calculation, just change the hour of the day / day of the year to start the calculations. Whenever one tracker "hides" another, the second will become interfered, and automatically highlighted in red colour. The interfered tracker will keep the red colour until it would be free from interferences again.

In our case "*Example 1*", interference occurs –for example- at day Nº 30, hour +3h. The interference disappears again at hour +3.5h
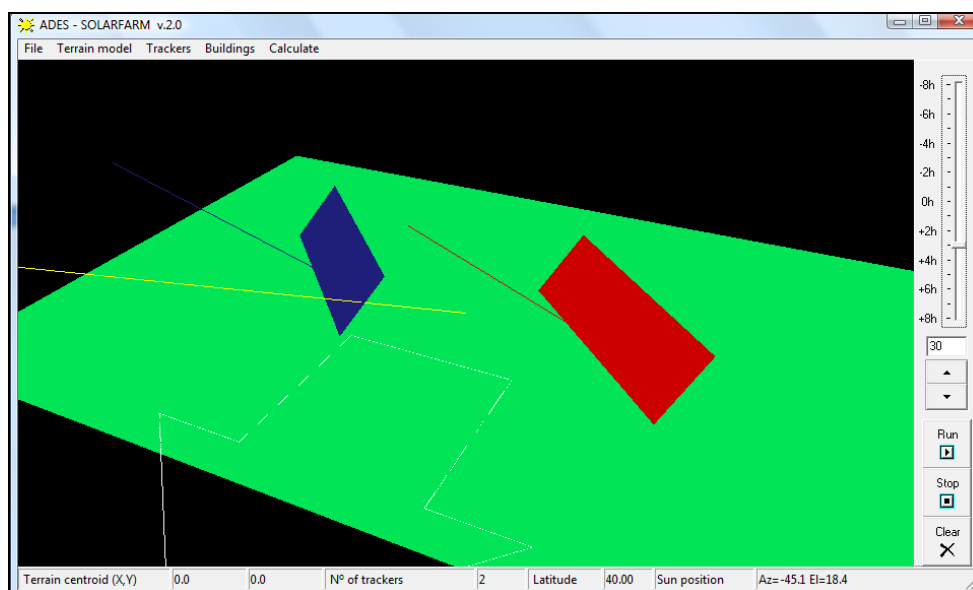
Interference can be geometrically checked: right-click anywhere in the screen, this will open a contextual menu
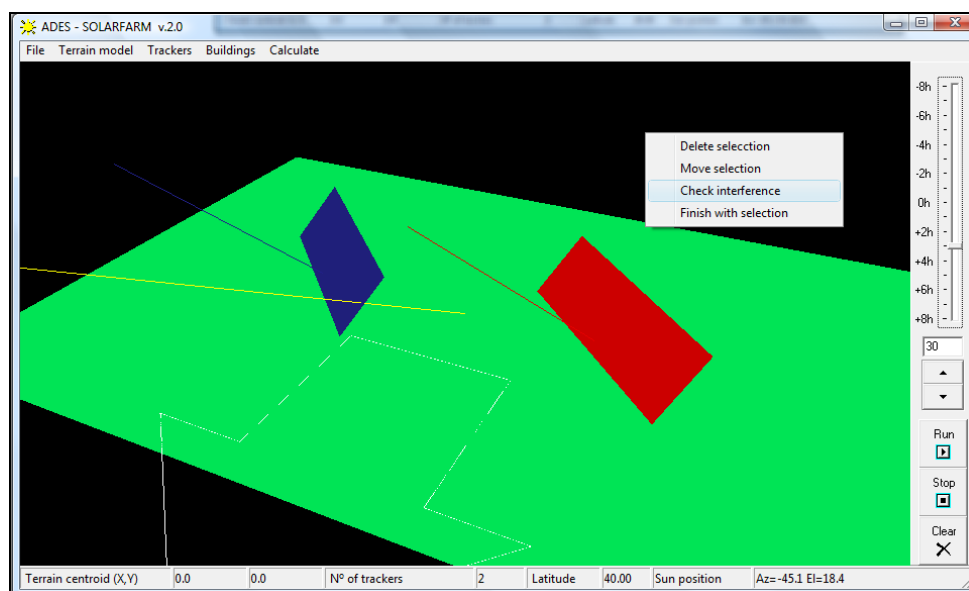
Select the *Check interference* option to highlight solar beams at interfered tracker corners. Interference occurs when a sun beam from one tracker corner intersects other tracker's or building's surface, as shown in the following screen:
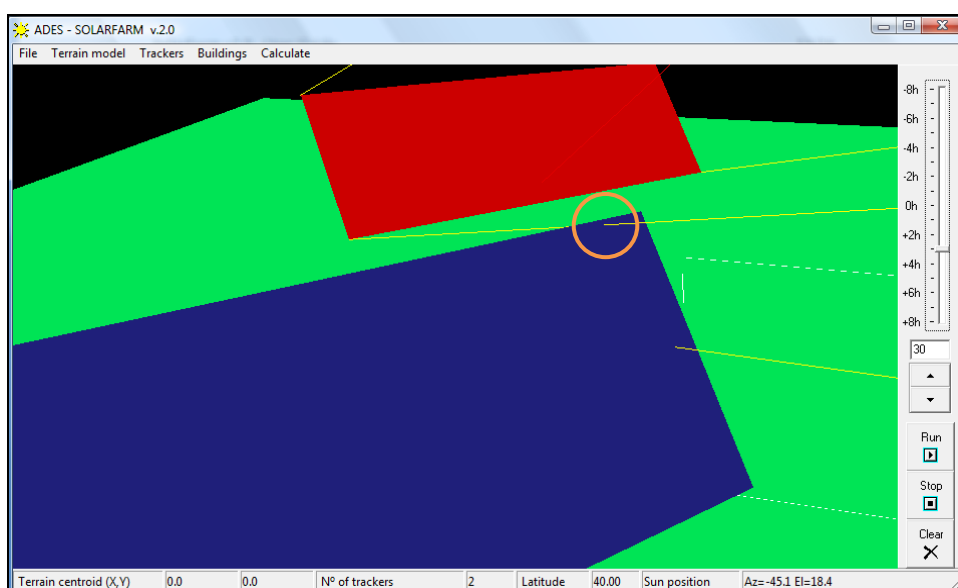
Interfered tracker will be partially shaded by the second one during this half hour. Because the "*Example 1*" case is symmetric with respect to South, the same interference will occur for the respective tracker in the period -3h to -3.5h (morning).

3.4.2   Moving trackers

To avoid this interference, distance between trackers should be increased. The procedure to move a tracker is as follows:

- Click the right mouse button anywhere on the screen to find the contextual menu again.
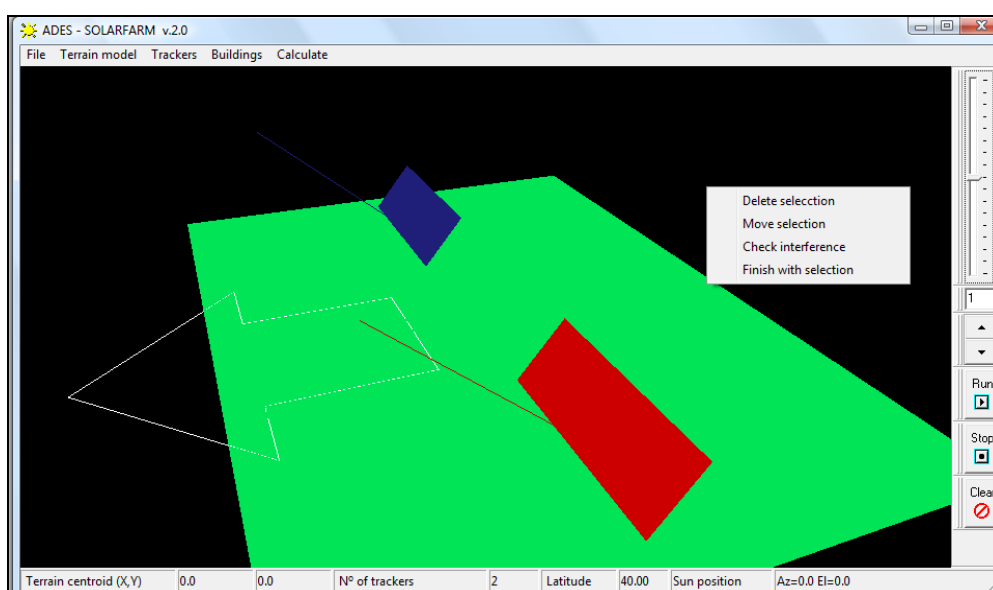
- Select the option "*Move Selection*". A coordinates dialog will appear. Enter the following displacement to move the selected tracker 3 meters away from West to East
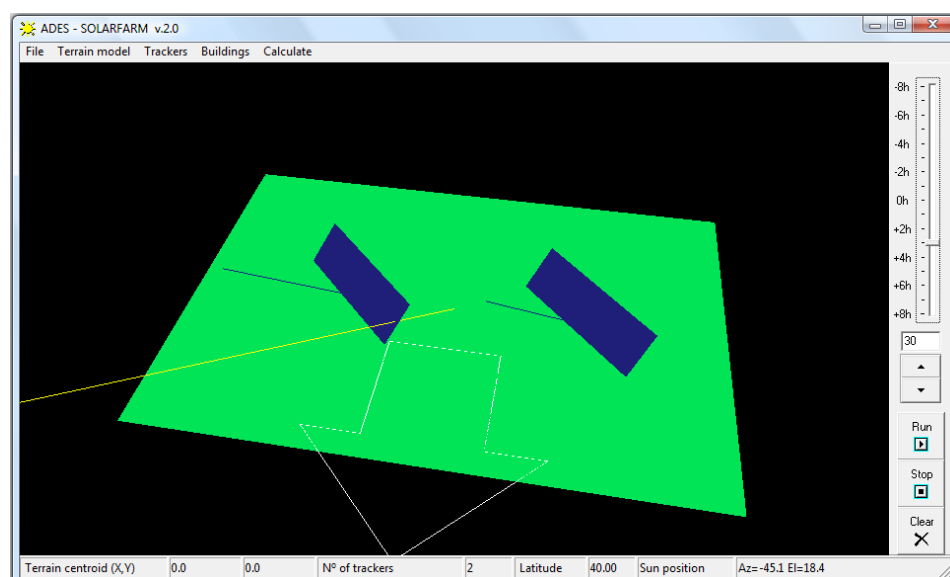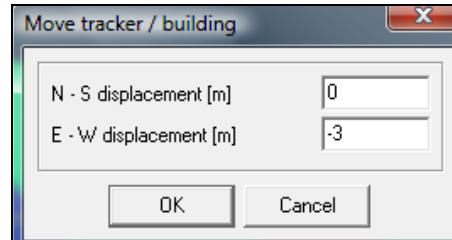
- Click-right to find the contextual menu once more, and select "*Finish with selection*".

3.5   Other basic operations

The contextual menu can be called anytime to perform any of the following operations with scene objects:

- Delete
- Move
- Interference check
- Refining local mesh

The above operations will apply to <u>all the selected trackers</u> when invoked. Selected trackers are highlighted in red colour. A tracker can be selected as consequence of an interference analysis (as explained before) or manually by the user.

To select a tracker manually, just left-click on it on the graphic screen. Once you finish with the required operations select "*Finish with selection*". This will reset all selected trackers, even if they are interfered from previous analysis.
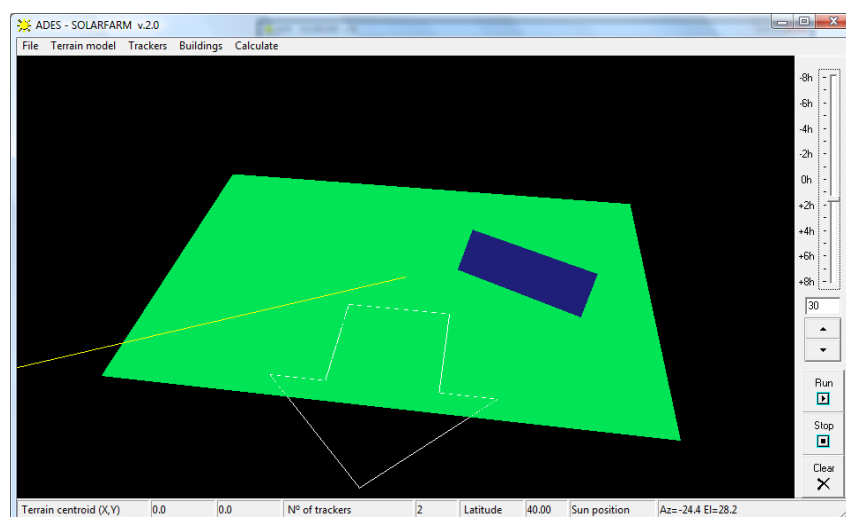
Tip: To reset a selection, you can also left-click on the selected tracker again.

3.5.1   Selecting and deleting a tracker

Back to our case, left-click on one tracker to manually select it
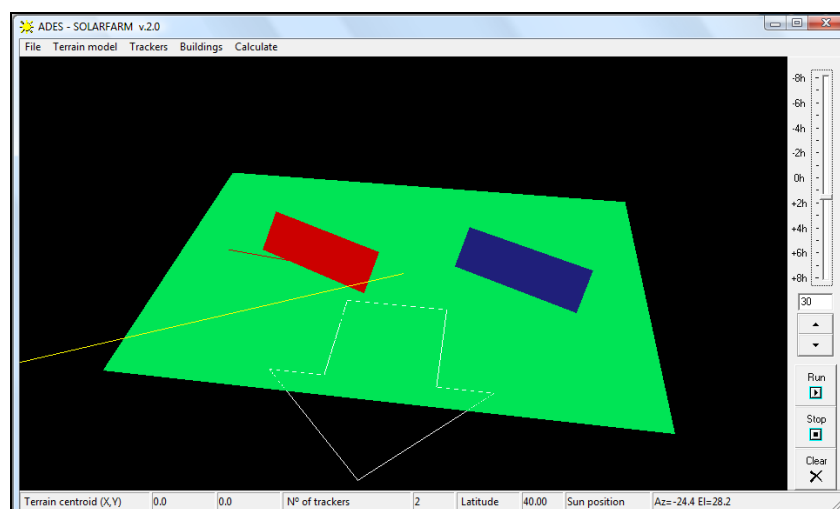
Right-click to find the contextual menu and select "*Delete selection*", to delete the highlighted tracker:

Note: Deleting a tracker also clear all previously calculated terrain shading.

4   Guided Examples

In this chapter we will create two new cases and introduce terrain management and photovoltaic plant tracker distribution.

4.1   Creating a base terrain plant

A base terrain is a flat-horizontal terrain mesh of given rectangular dimensions and mesh resolution. Also site latitude in specified when creating the base terrain.

For example, we will create the following base terrain:

- N-S side length   = 100 m
- W-E side length   = 240 m
- N-S number of elements   = 50 elements (i.e., length of elements = 2m)
- W-E number of elements   = 100 elements (i.e, length of elements = 2.4m)
- Latitude   = 38.6º N

Click on the *Terrain model* menu item and select the *Create base terrain...* option. This will open the following dialog, where the above values are entered:
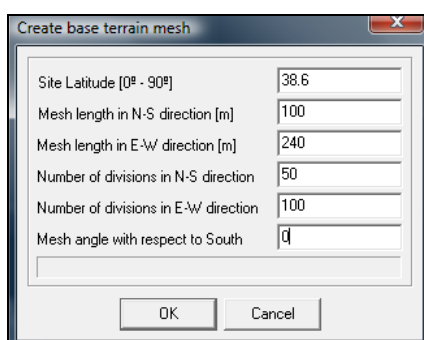
Accepting this will create the following terrain mesh. Relevant parameters can be checked at the Status bar.
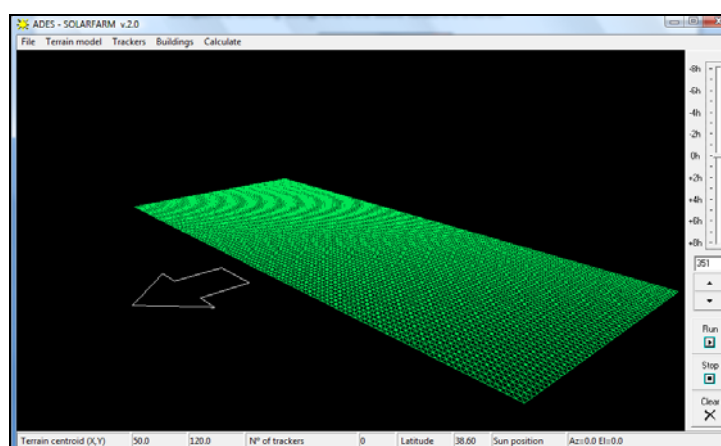
Note: The parameter "*Mesh angle with respect to South*" in the previous dialog is used when the base terrain mesh is to be rotated a certain angle, however the input lengths of the mesh sides (N-S & E-W directions) should be entered as total lengths, and not as projected lengths in such directions.

Mesh resolution (i.e, dimension of triangles) is relevant for precision of shading results. The finest the mesh resolution, the more exact the shadow shape will be. As a counterpart, a very fine mesh will take more CPU time for solving.

4.1.1 Adding trackers

To add trackers to the base terrain click on the *Trackers* menu item and select the *Add...* option. The following dialog appears:
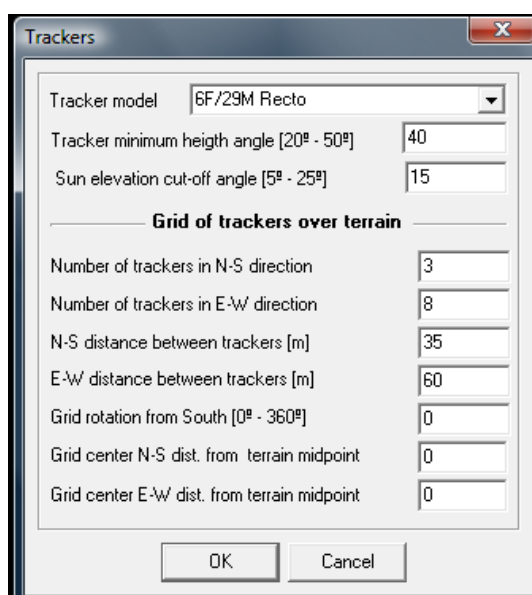
The input defines a grid of trackers of the selected ADES *Tracker model*. The fields are as follows:

- *Tracker minimum height angle*: Is the minimum angle between the horizontal plane and the line perpendicular to the tracker plane (i.e., zero angle means that the tracker plane is completely vertical). This value is function of the constructive characteristics of the tracker, and should be confirmed by ADES for each project. A standard value is 40º.

   Sun elevation cut-off angle: Shadows length tends to be infinite at zero sun elevation angle, but irradiance is then negligible. For those reasons there is a need to define a threshold sun elevation angle under which production of the photovoltaic plant is not relevant (generally because inverters do automatically switch-off under this irradiation level). SolarFarm will not calculate shadows nor interferences at sun elevations below this *sun elevation cut-off angle*. Also, the sun beam yellow line in the graphic screen will change to grey colour when sun elevation is bellow the user defined cut-off angle.
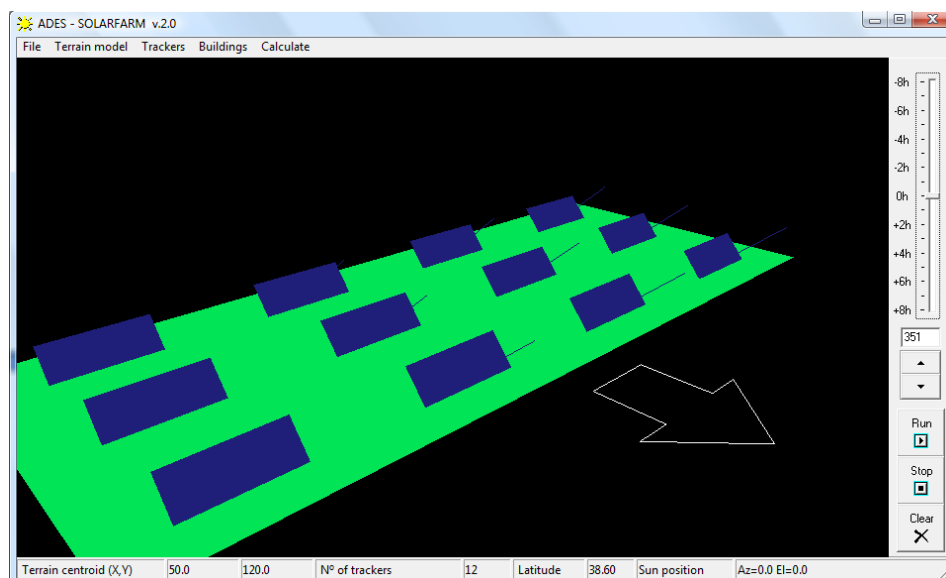
-   *Number of tracker is N-S direction*: Number of tracker rows in the tracker's grid.

-   *Number of tracker is E-W direction*: Number of tracker columns in the tracker's grid.

-   *N-S distance between trackers*: Distance between tracker rows in the tracker's grid.

-   *E-W distance between trackers*: Distance between tracker columns in the tracker's grid.

-   *Grid rotation from South*: { actually disabled option }

-   *Grid centre N-S distance from terrain midpoint*: Is the distance between the centre of the tracker's grid and the center of the terrain, projected in the N-S direction.

-   *Grid center E-W distance from terrain midpoint*: Is the distance between the centre of the tracker's grid and the centre of the terrain, projected in the E-W direction.

We will create a grid of 3 x 8 trackers with the following parameters:

Tracker distribution is shown in the following screen shot:

We have specified a tracker's grid of 3x8 units, however half of the trackers were out of the terrain limits according to the input grid dimensions. Solarfarm do not create trackers which coordinates are out the terrain mesh domain, therefore just 12 units are fitted.

4.1.2 Adding buildings

To create a building, click on the *Buildings* menu item. The following dialog appears for data input:

Enter the building dimensions -height, width, depth- and the building centre offset from the grid midpoint (similarly as for the tracker's grid). Also the building orientation angle with respect to the N-S direction can be defined. With the above data, the following building is created. A tracker has been manually deleted in that place.
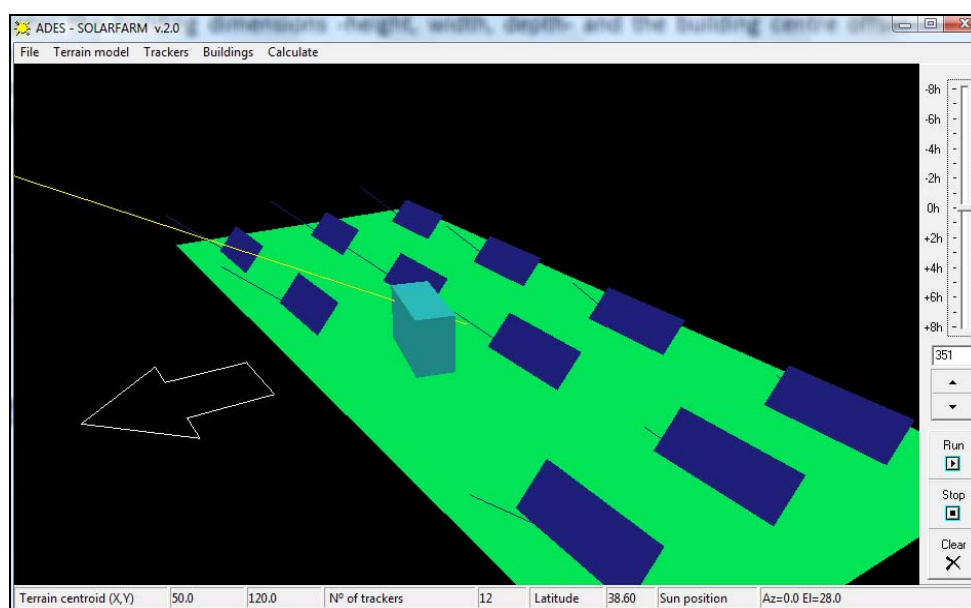
Buildings can be selected (left-click) for contextual menu operations (deleting, and moving), as for trackers.

4.2 Analysis

The following image shows the complete-year shading calculation for this case:
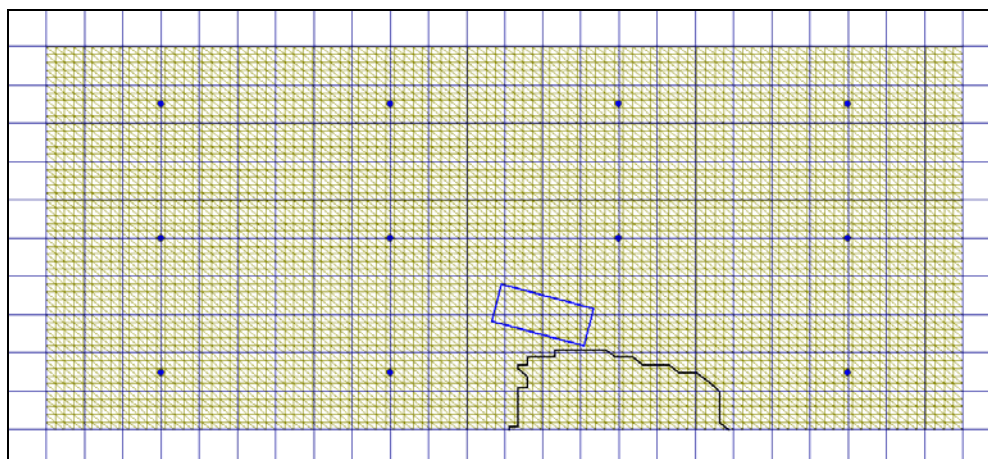

Almost the whole terrain is sometime shaded.

The interference analysis shows that the highlighted trackers are partially shaded for some hours every day, from day 351 to day 75. This apart of the interferences caused by the building, which affects only the two closest trackers:
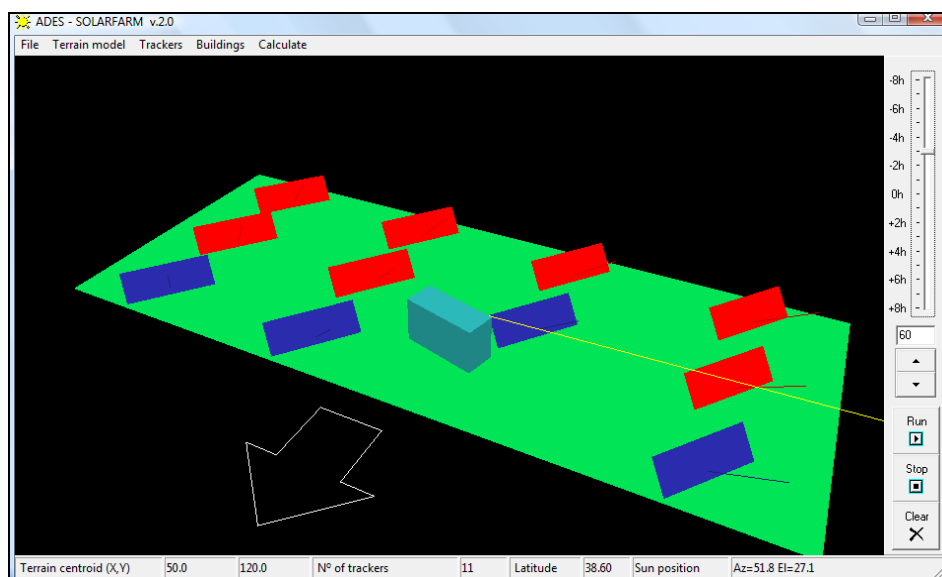
To solve this, we can mover trackers rows independently some meters away each other in the N-S direction, or delete all trackers and create a new tracker´s grid.

> **Tip:** To select all trackers click on the *Trackers* menu item and select the *Select all* option.

The following new grid is tested (N-S distance increased up to 40 m):
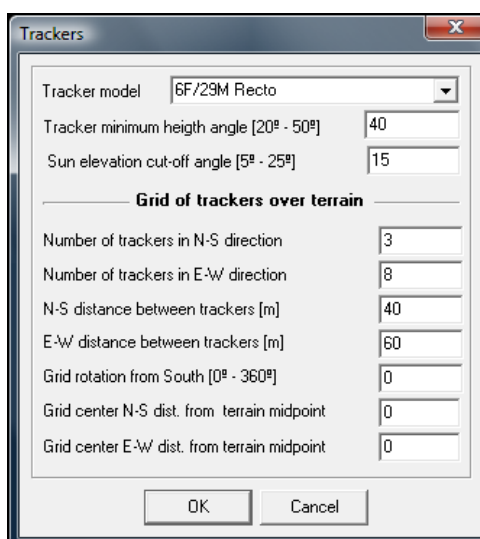
This grid produces minor interferences between days Nº 360 and Nº 36, which is an acceptable result for our particular criteria.

Interference with building is restricted to one tracker. With this tracker's grid the solution is to eliminate the tracker. The final layout is as shown in the following screen shot:
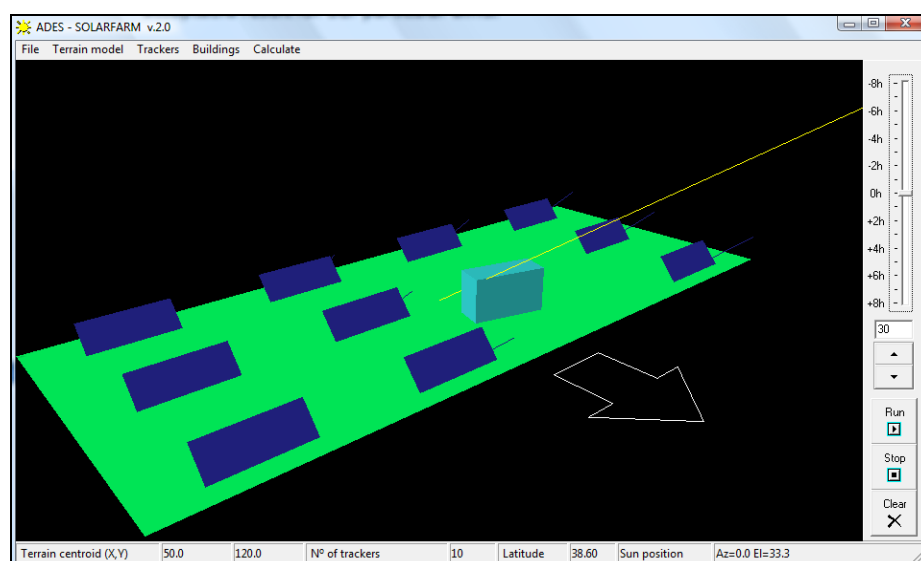
4.3 Discussion

The tracker selected in the previous case is ADES 6F/29M Recto. The annual shadow of this machine at the considered latitude (38.6º N) and a sun elevation cut-off angle of 15º is as follows (5m measuring grid), i.e., 72 m (E-W) x 55 m (N-S).
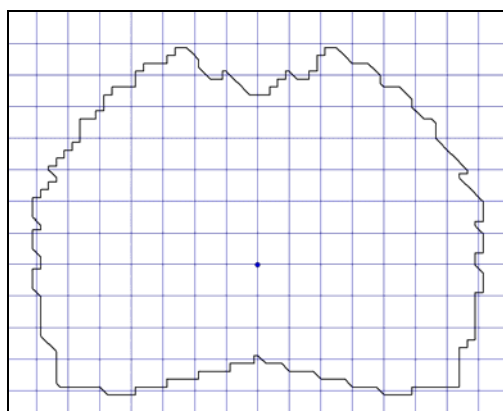
Obviously, a tracker's grid of 72 m x 55 m will produce no interference between trackers. However this grid is not necessarily the optimized solution. In this particular case, the minimum tracker's grid dimension that will not produce any interference is the square grid 46m (N-S) x 46m (E-W). The optimal grid dimensions are obtained by iterative checking.

This is only true for a perfectly flat and horizontal terrain. In real cases terrains will rarely have such ideal conditions, however analyzing a *Base Terrain* case with a 4 trackers grid before going through real topographic data, gives a first idea on how to start with the design of a power plant.

4.4   Creating a plant from topographic data

SolarFarm can import standard *dxf* files with 3D-face triangular elements. It is common for commercially available topographic and GIS software to produce digital terrain models as 3D triangular meshes from a set of surface points measured on site, and export the final digital model in the required *dxf* format.

To import a digital terrain model click on the *Terrain model* menu item and select the *Import Digital Terrain Model* option. The following message will appear:
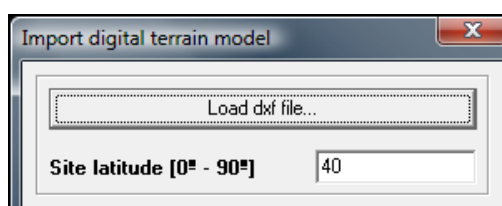
Before calling to *Load dxf file...,* it is important to specify the site latitude in the edit box. Then click on the *Load...* button and find the dxf file you wish to import:
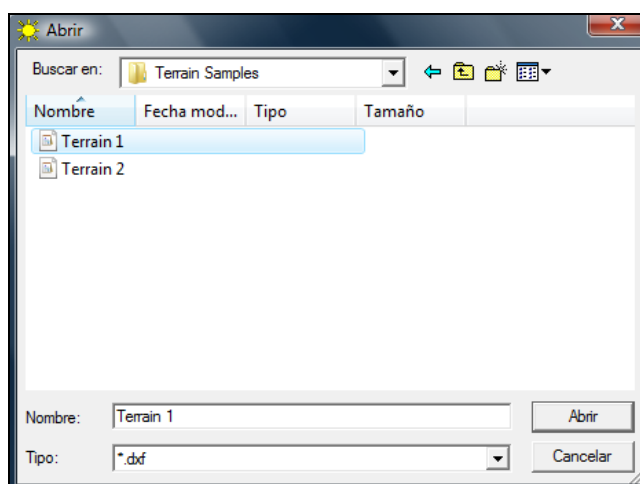

SolarFarm includes two sample dxf files in the "Terrain Samples" directory. We will select "*Terrain 1.dxf*" in this chapter.

> **Note:** dxf files are text files that can be edited with any standard text editor, containing a number of information "blocks", each block describing a graphic object (POINTS, LINES,…etc). When reading the file, SolarFarm will skip all the information blocks except those containing 3D faces. In dxf format, these blocks have the header `3DFACES`.
>
> If you are having any trouble when importing geometry to SolarFarm, open the dxf file with any text editor and check if your terrain mesh file includes these blocks (one block per triangle).
>
> `3DFACES` are also used to define rectangular mesh elements. SolarFarm will only read the first three points of the block to import the corresponding triangular terrain element, so be sure that your file contains only triangular elements.

In our case, site latitude is 38.6ºN. Once opened, the imported terrain looks as shown in the next screen:
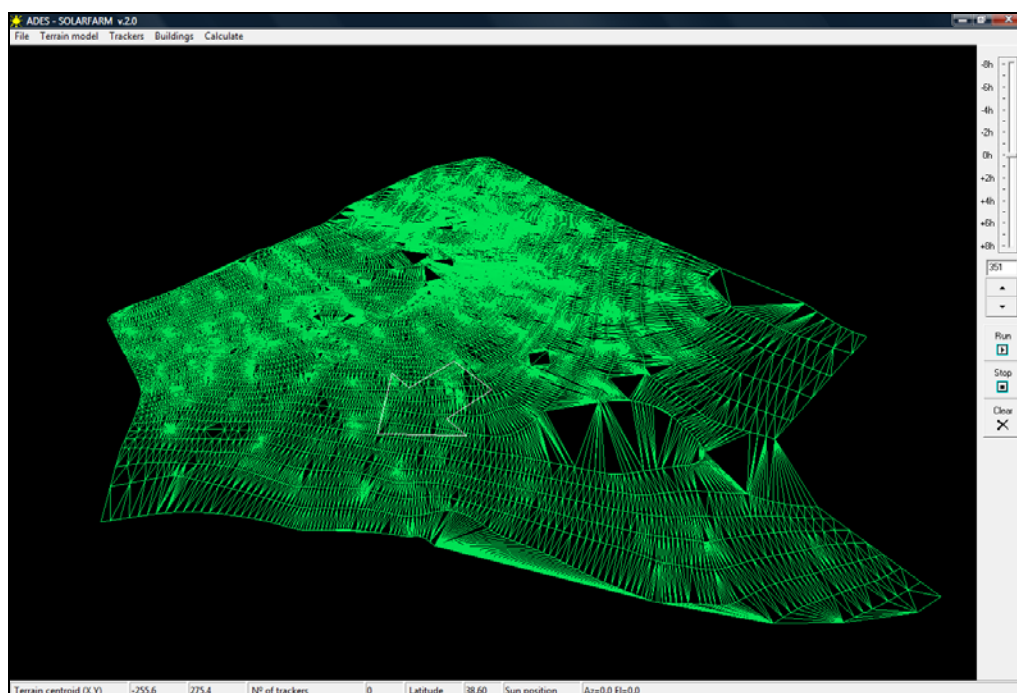
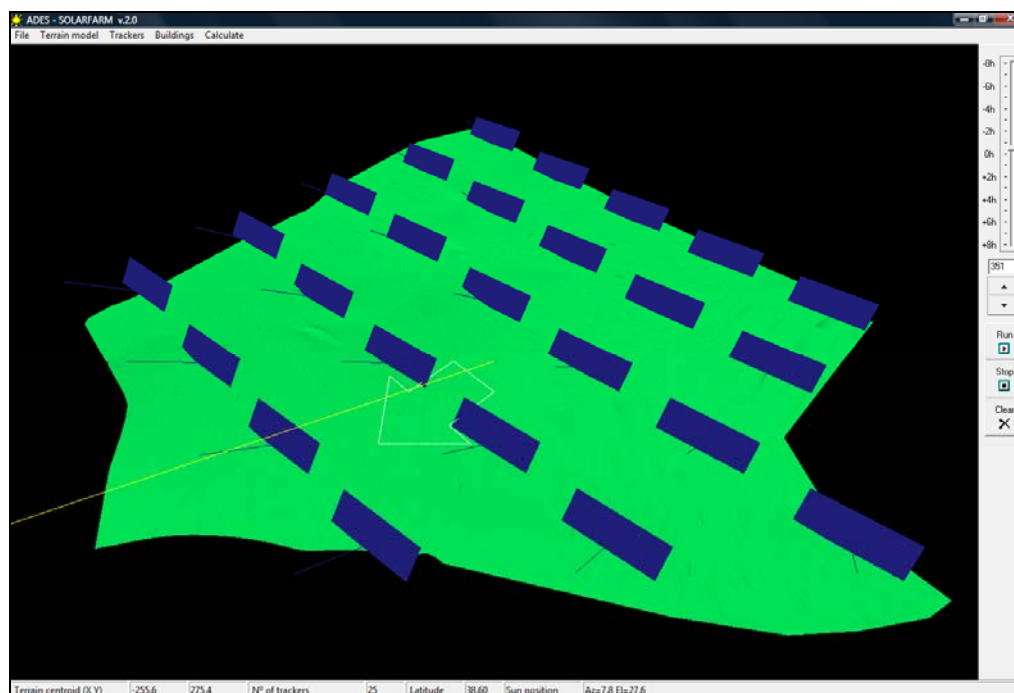If you wish to check the terrain and mesh size dimensions, open the print screen
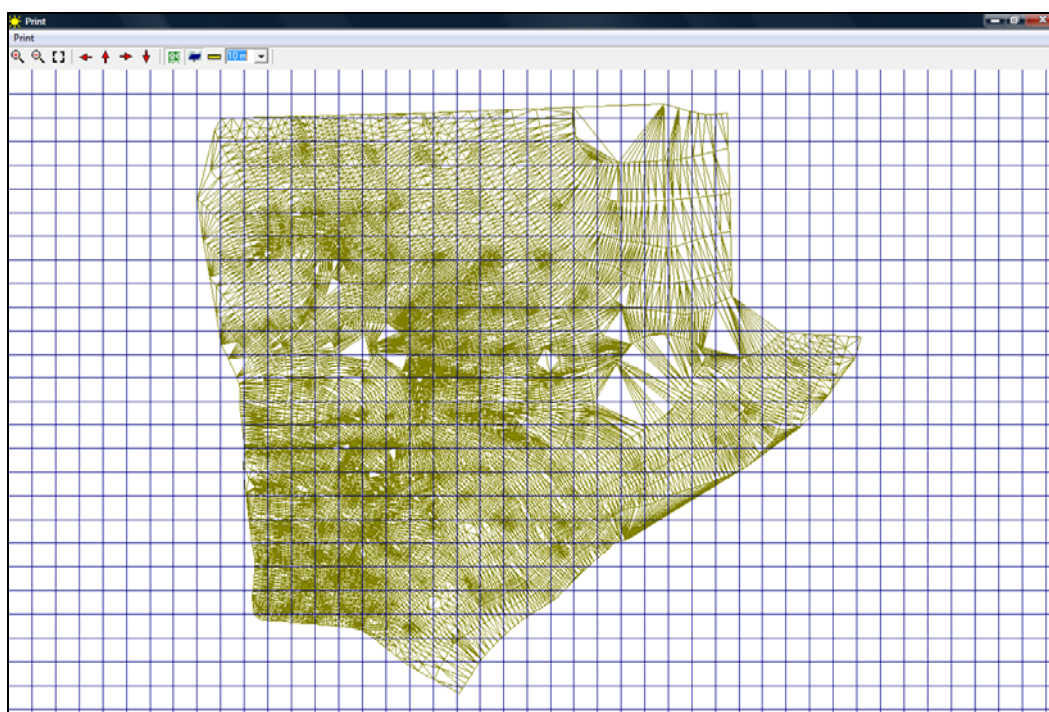
Terrain dimensions are 245 m (N-S) x 180 m (E-W).

4.4.1 Trackers grid

We choose the tracker model ADES 6F/29M Recto, with a grid dimension of 46m x 46m (optimal for flat horizontal terrain at Lat 38.6ºN). The input dialog is as follows:
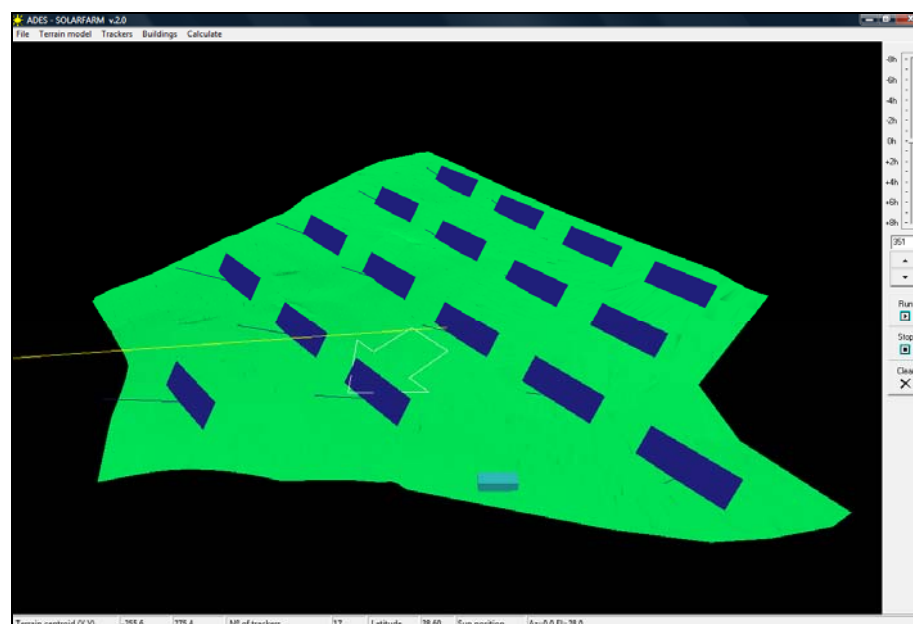

And the result layout is

North side and West side trackers are too close to the terrain limits. The whole grid is now displaced the following distances:

N-S displacement   =   10 m (i,e, towards South)
E-W displacement   =   -30 m (i,e, towards East):

After deleting out-of terrain trackers and locating the transformer building, the layout looks as follows:

Now we perform some shading calculations -just for day numbers 351, 81 and 171- to obtain a first check. The result is shown in 2D view (terrain hided):
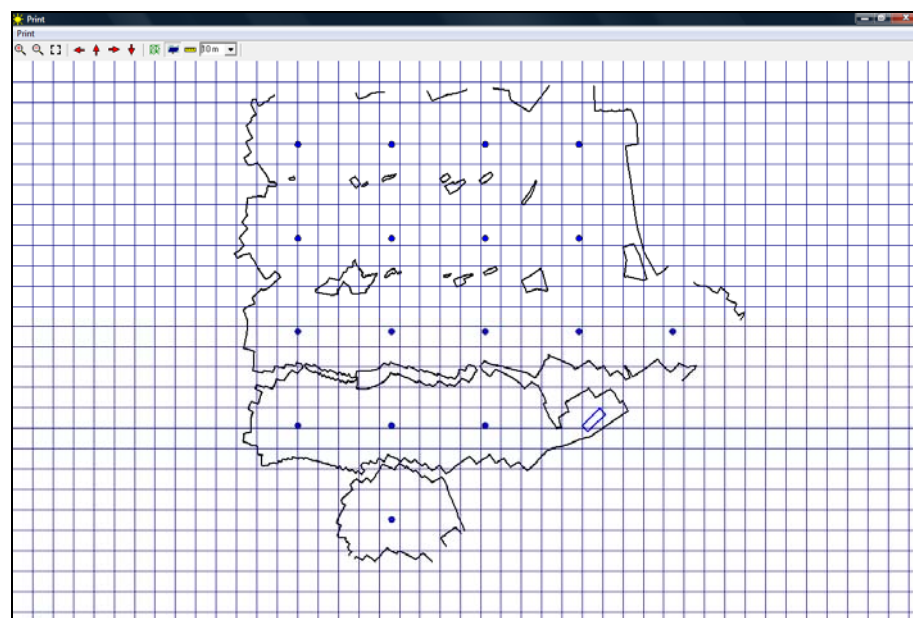

Shadows are irregular because terrain is not horizontal. As can be seen, the terrain under the three lower rows has a slope downwards South-East, therefore the N-S dimension of the shadows is shorter but the East part is longer than the West part. Terrain under the two upper rows has a slope downwards North-East.

In both cases, interferences will occur some days at afternoon.

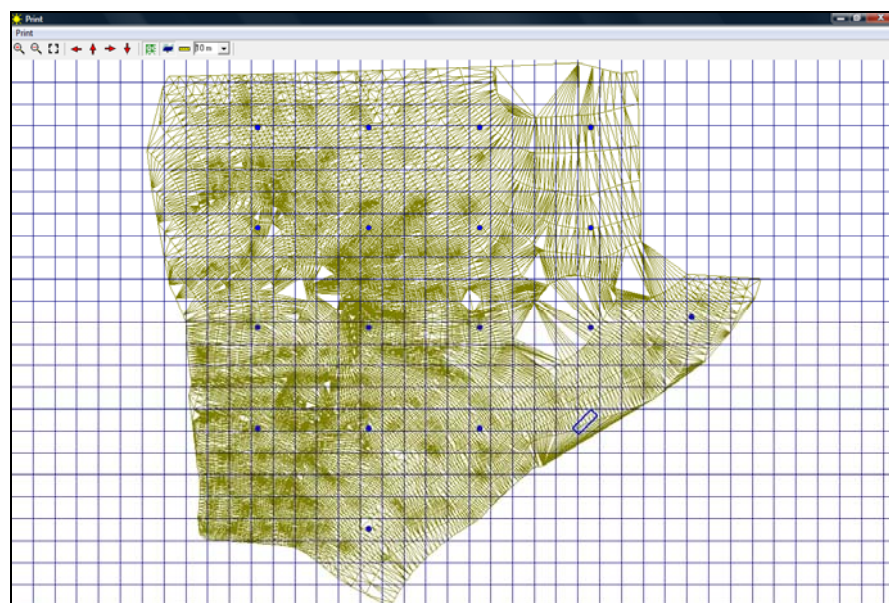### 4.4.2 Interference Analysis

An interference analysis is performed. For instance, day 35 at +3.5h has the following interference map:
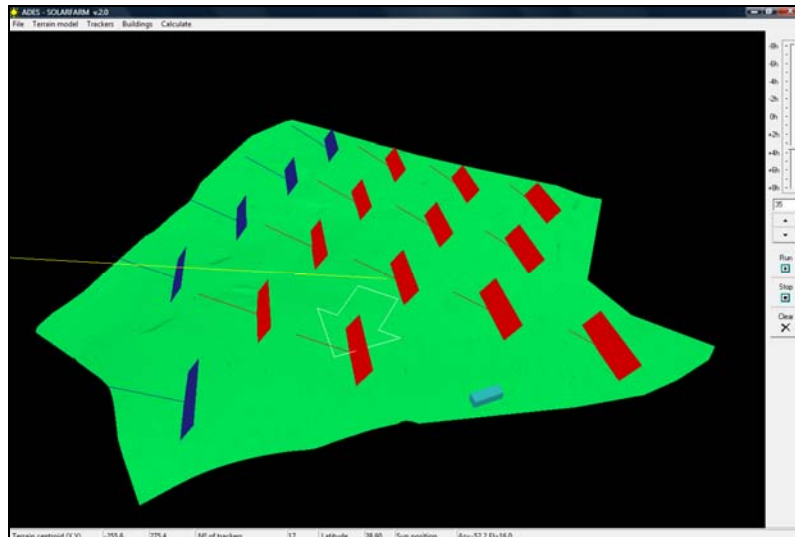
We will move trackers columns to increase distances between them

First column (four trackers)   : displaced 5m towards West.
Second column (five trackers)   : Unchanged
Third column (four trackers)   : 5m towards East
Fourth column (three trackers) : 10m towards East
Fifth column (one tracker)   : 10m towards East & 5 m towards North

Grid layout is now as shown:

Now, the interference analysis gives the following incidences (day 53, +4h):
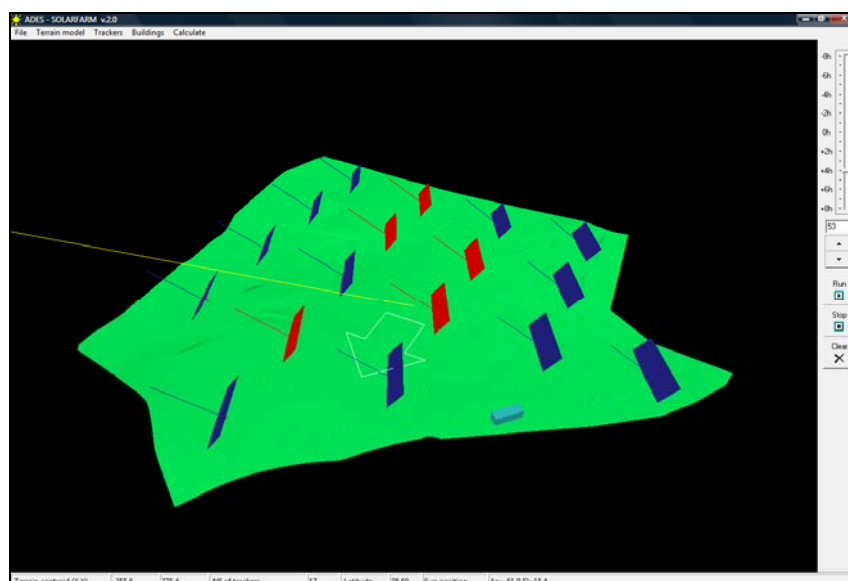
Since not all trackers in rows or columns are interfered, it is a good practice to start displacing individual trackers for detail optimization.

> **Tip:** Moving one tracker to release its interfered condition may produce new interferences at other units. The optimization process conclusion might be changing the tracker model, or increasing the sun elevation cut-off angle.

After several iterations, the following plot shows a solution for this case:
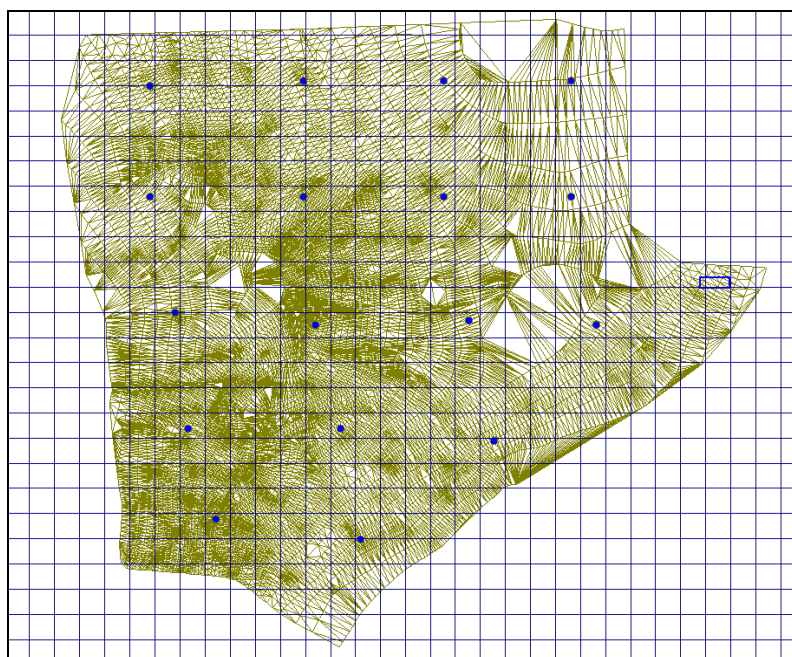
This case is provided as "*Example 2.sff*" in the *Samples* directory.

4.4.3 Some more about terrain mesh. Refining

3D terrain meshes, created by appropriate software, are suitable to define large scale geometry such as geographical topology (say, a mean of 10m length for the mesh triangle-side). However, a shading analysis requires a mesh of much smaller scale (say, 2m) to calculate a precise shadow profile.

When analyzing a plant from topographic data is sometimes convenient to obtain a precise shadow. This might be necessary if a tracker or building is close to irregular topography. If this is the case, the terrain mesh can be locally refined by SolarFarm under the selected tracker.

As an example, open terrain sample file "*Terrain 1.dxf*", and activate the *Terrain model/View/Wireframe* menu item to check the terrain mesh resolution.
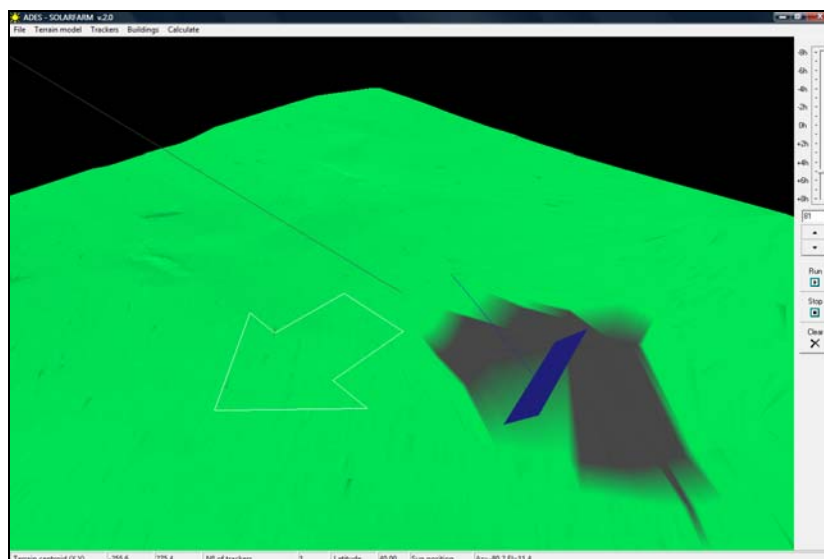
Add a single tracker with the following data:
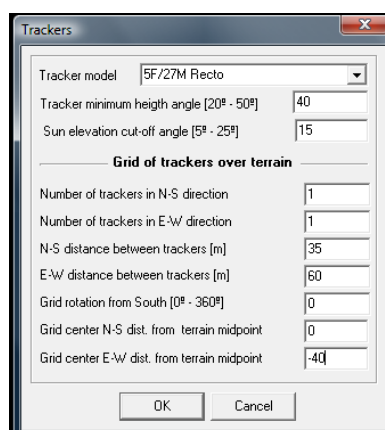
The tracker is located on a very coarse terrain mesh area

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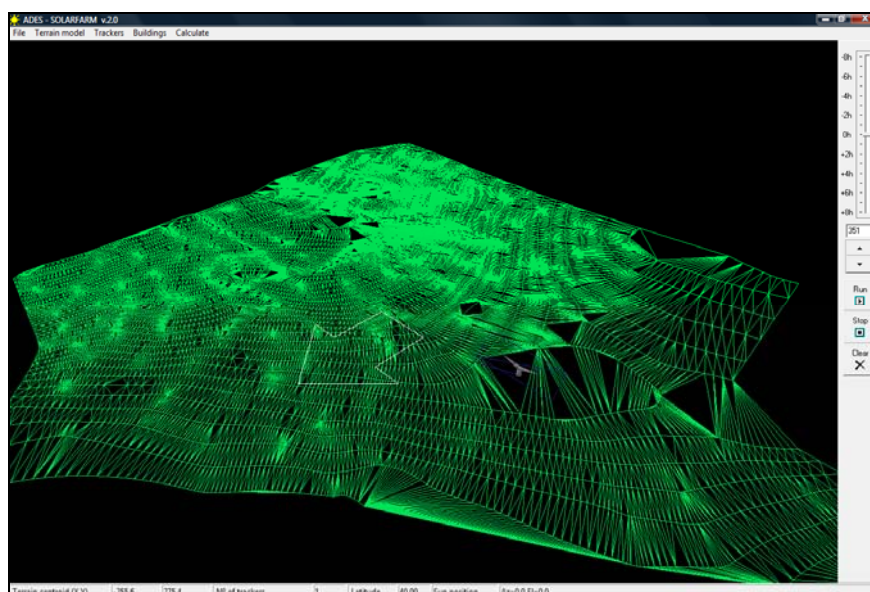
When trying to calculate terrain shading the result is very poor, according to the terrain mesh resolution in that area.

To refine the mesh locally, select the tracker and open the contextual menu to select the *"Refine local mesh"* option. This will open the following dialog box:
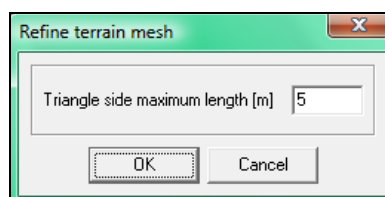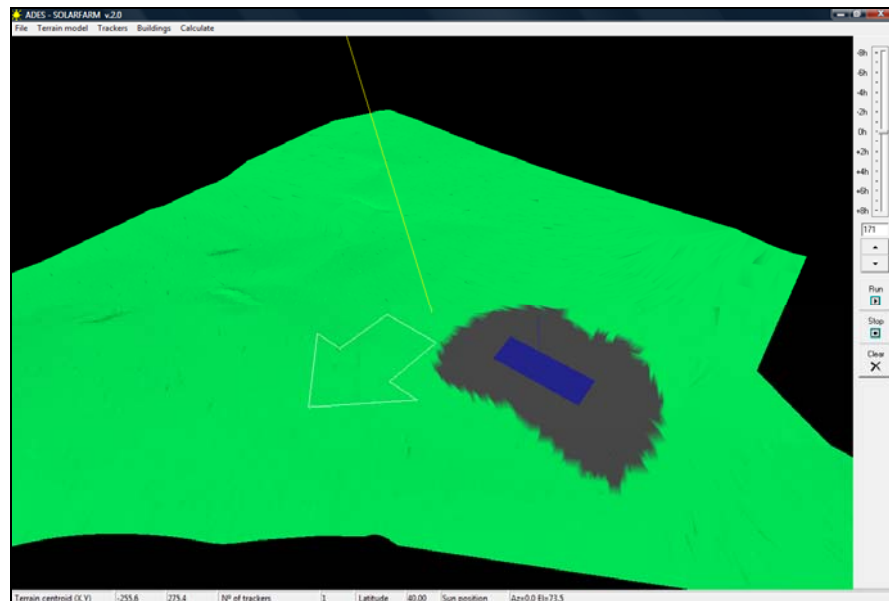

Enter the desired mesh resolution by defining the terrain mesh triangle maximum side length, and accept the dialog. This will subdivide some large triangles around the tracker into smaller ones.
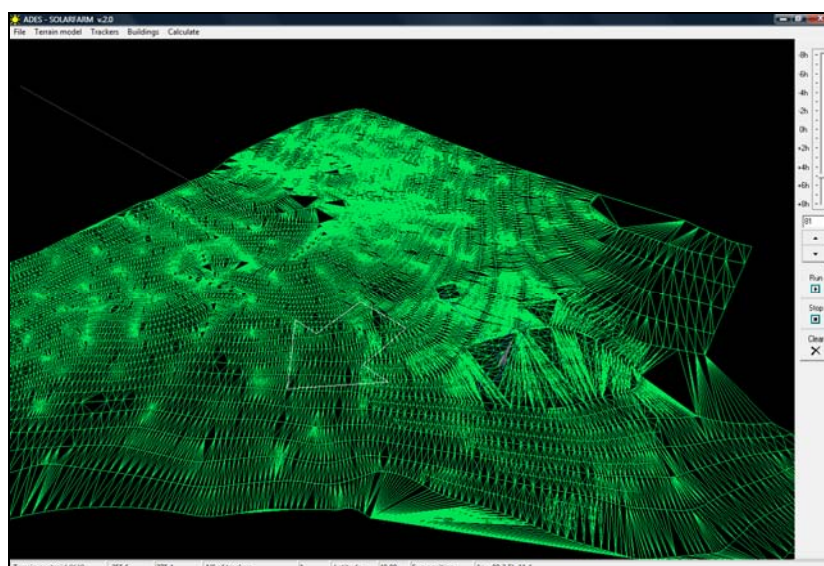
Call the contextual menu again to "*finish with selection*". Now the mesh is good enough to perform a shading calculation

> **Notes:**
>   - Mesh refining is a powerful tool to calculate shadows accurately in complex terrains. Counterpart is that adding triangles to the mesh terrain will increase the calculation CPU time.
>   - Maximum number of terrain mesh triangles is limited to 120.000.
>   - When creating a terrain mesh in any specific software before importing to SolarFarm, consider that a coarse terrain mesh will speed up your calculations and restrict memory usage. Use the refining option afterwards from within SolarFarm if needed.