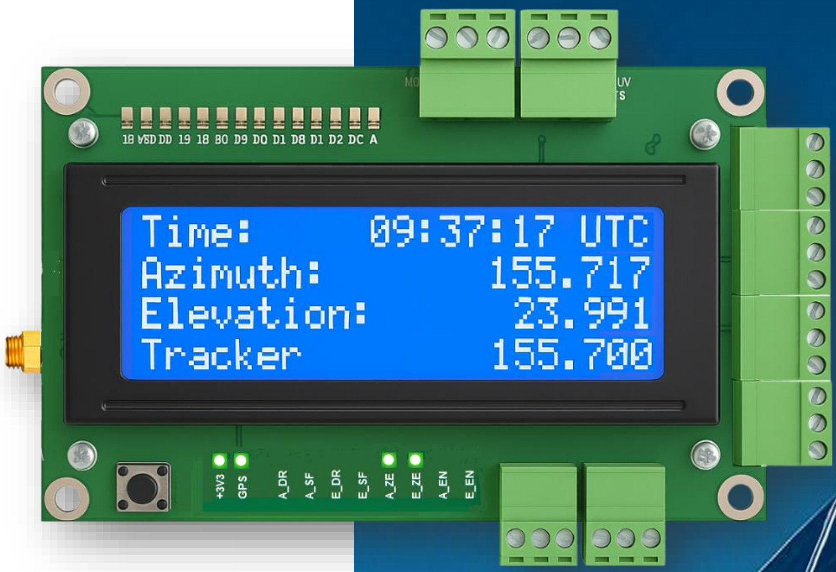
AsTrA TRACKERS

Solar Tracker Controller mod. ATC2A

Getting Started Guide and Application Notes



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Preface

This text is not intended to be exhaustive, but only to give general information that will help to better clarify some of the main concepts regarding solar trackers.

Solar tracking technology significantly increases the energy output of solar panels, photovoltaic or solar thermal collectors.

The adoption of this technology is crucial in solar concentration plants.

Designing the mechanical structure of a Solar Tracker, commonly referred to as a Tracker, requires knowledge of specific technical, mechanical and astronomical notions.

Azimuth is defined as the apparent motion of the Sun along the horizon from East to West (i.e. the variation of the Azimuth). Elevation is defined as the variation of the Sun's apparent height above the horizon until it reaches its maximum height in the sky.

The 'maximum excursion of the Sun' refers to the maximum variation of the Sun's apparent position in the sky during the year, on both axes, at a given point on Earth. This excursion is the result of the tilt of the Earth's axis with respect to the plane of the Earth's orbit around the Sun.

Understanding the meaning of *'maximum sun excursion'* is crucial to designing solar tracking systems, as these must be able to adapt to changes in the Sun's position while maximising sunlight absorption

However, the choice of using a solar tracker deserves a cost-benefit analysis. With the same number of panels installed, an increase in power output of around 30% more than with a fixed system can be achieved.

For large and medium-sized installations, the investment is definitely worthwhile. However, this technology is also used on smaller installations, especially where more power is required on less available space. In fact, it is not uncommon to see solar trackers on industrial warehouses or flat-roofed civil buildings.

1. Reasoned choices

The operating logic described here is the result of years of testing and experience, gained through the use of calculation software and the testing of mechanical test structures.

Our controllers, combined with a simple mechanics management system, are today the best technical-economic compromise aimed at obtaining a professional, reliable and highly competitive product compared to other solutions

This is why we have adopted standard elements and components to guarantee reliability, ease of maintenance and availability.

1.1 Solar trackers

Solar trackers can be divided into two types:

- **Active trackers**, in case they are set in motion by electric motors.

- **Passive trackers**, in case they are set in motion by autonomous physical phenomena, such as thermal expansion of gases, metals or whatever.

2. Type of command

Active trackers are in turn distinguished according to the type of control that manages their movement:

- **Sensing tracker**, in which the command is derived from information from several sensors that detect the position of the brightest point in the sky.

  This mode operation guarantees correct and precise tracking of the Sun, but only under clear sky conditions, becoming in contrast extremely uncertain and approximate under partly cloudy conditions.

- **An astronomical tracker**, the management of which relies on complex calculations to know the position of the Sun based on the coordinates of the installation site at the date and time.

  This operating principle ensures accurate and precise tracking of the sun even in partly cloudy conditions, guaranteeing higher productivity in relation to direct light, and is absolutely indispensable in concentration plants.

2.1 Solar trackers and their characteristics

A mechanical system that handles both axes (Azimuth and Elevation) offers superior performance in terms of energy produced compared to a single-axis system. However, a dual-axis system is more complex and expensive

A single-axis tracker on the Elevation axis is inefficient, as the energy produced would be significantly less than a solar tracker on the Azimuth axis

However, it is not possible to indicate with certain values what percentage increase is obtained by moving one axis in relation to the other, as everything depends on the latitude of installation of the system

In fact, the apparent motion of the Sun during the course of the year at a latitude (e.g. 45° central Europe) is quite different from that at an equatorial latitude.

Purely by way of example, the average annual yield obtained by simulating three different types of solar trackers, compared to a fixed system of the same characteristics, is shown.

Latitude: 44.907615 N
Longitude: 8.608845 E

Azimuth axis tracking system	***+ 24,80%***
Dual-axis tracking system (Azimuth + Elevation)	***+ 29,20 %***
Inclined-axis tracking system (or polar axis)	***+ 24,60%***

(Data taken from Solergo photovoltaic design software)

Moving the Elevation axis is therefore only useful in particular situations, but always as a supplement to Azimuth tracking.

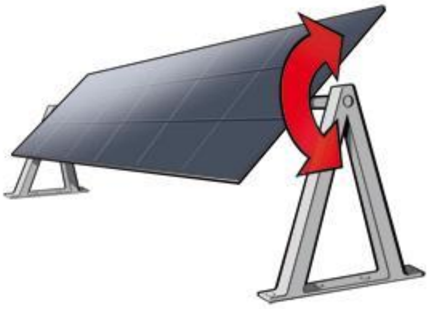
Simulating a single-axis tracker for the elevation axis only, the efficiency does not exceed 10% in the best case

Some mechanics of single-axis Azimuth trackers are designed to manually move the Elevation axis twice a year, coinciding with the Equinoxes.

The structure will therefore have to be constructed in a totally different way depending on where it is installed.

Through a few images we can better clarify these concepts, without considering the mechanics that move only the Elevation axis.

Horizontal single-axis tracker
(Simple and suitable for large solar plants)



The single-axis horizontal mechanical structure (Azimuthal) is utilized in large installations worldwide due to its simplicity. It is recommended for equatorial latitudes. To further optimize system performance, the rotation axis of the structure can be tilted towards the Equator by the same number of degrees as its own latitude.

Independent two-axis tracker
(Suitable for latitudes over 45°)

The most sophisticated trackers have two degrees of freedom, with the aim of aligning the solar panels on both axes with respect to the Sun.

Using this type of mechanics, increases in energy production of up to 30 per cent or more can be achieved.

Tilted-axis tracker, or polar axis
(Suitable for latitudes from about 20° to 45°)

Polar axis trackers move on a single axis inclined to the ground and parallel to the earth's axis of rotation.

This system of rotation around a single axis manages to keep the solar panels almost perpendicular to the Sun throughout the day (neglecting summer-winter oscillations in the Sun's trajectory), offering an excellent compromise in terms of efficiency that can be obtained from a single-axis Azimuth tracker.

3. Main features ATC2A controller

- ### Astronomical Control System - Digital

Our Tracker control and positioning system is based on an advanced algorithm, managed by a designed and programmed electronic board. The calculation algorithm returns the angular degrees of the Sun on both axes, in real time and with high accuracy. The geographical co-ordinates of Latitude and Longitude, date and time, are automatically acquired through a GPS receiver module integrated on the board, guaranteeing the correct functioning of the system.

- ### Modes of operation

The ATC2A Controller is designed to be able to handle either Stepper Motor or VFD Inverter drivers.

- ### Zero position self-learning

When switched on, the Controller starts a self-learning procedure to determine the zero position, corresponding to local solar noon. This position is acquired by means of a metal cam installed on the moving part of the Tracker, which is detected by a proximity switch mounted on the fixed part of the structure. Once this phase is completed, the Tracker automatically orients itself towards the Sun. The Controller's display shows the date, time, Azimuth angle, Elevation angle and current position of the solar tracker in real time

- ### Independent management for Azimuth and Elevation

The controller calculates the position of the sun and automatically manages the tracker on both axes. In the case of single-axis mechanics, no changes to the circuit board are necessary.

- ### Automatic positioning and date/time control

During normal operation, the controller periodically verifies the correct position of the Tracker in relation to the data shown on the display. The verification procedure also concerns the synchronisation of the microcontroller's internal clock, based on the data received from the GPS. However, in the temporary absence of a signal, the internal clock keeps the system running completely autonomously.

- ### Safety position in case of wind

The controller is capable of anemometer monitoring. In the event of strong winds, the Tracker is automatically placed in a safe position to minimise the possibility of damage to the structure

- **Software limit switches (Min and Max)**

The software allows you to set the angular limits within which the tracker can move. This function is particularly useful when the tracker's mechanical structure has an angular limit beyond which it cannot move

4. Choice of motor models and positioning control

The ATC2A controller allows the use of mechanical gearboxes coupled to stepper motors or AC electric motors.

Stepper motors are the ideal solution for applications such as this, which require high precision in angular displacement and speed control.

In the *'Closed Loop'* version (with integrated positioning control), these motors guarantee accurate and reliable positioning, eliminating the need for additional components for positioning feedback.

However, it is possible to use motors of different types, provided that a valid and reliable feedback system is implemented for the tracker's positioning control

Stepper Motor with Closed Loop Driver

Three-phase motor without positioning control

Note: 'Position feedback' is a sensitive element in the Solar Tracker control system.
An unreliable positioning control system can render any calculation of the Sun's position useless

Many gearbox models are available on the market, and it is possible to use any type, as long as they are correctly dimensioned for the intended application. The choice of gearboxes must, however, fall on models of good quality and reliability.

Worm gearboxes, slewing rings and axial gearboxes can be used for this application. These components, due to their specific technical characteristics, can be optimally matched to achieve high reduction ratios and efficient performance. This is essential to ensure precise and optimal operation of the Tracker

Indeed, it is rare to be able to achieve very high reduction ratios with a single gearbox, especially a small one. It is much simpler to couple two gearboxes. There are combination gearboxes on the market, which are very useful for this type of application.

Electric linear actuators can be used, provided they are equipped with a position feedback system compatible with the controller's characteristics, or driven by stepper motors.

Slewing ring and worm gearbox

Slewing rings and worm gearboxes are ideally classified as irreversible components due to their design. Static irreversibility occurs when, when the gearbox is stationary, the application of a load on the output shaft does not cause the input shaft to rotate.

A low reduction ratio can in fact cause rotation in the opposite direction to the correct one if a high torque is applied to the output shaft.

A worm gearbox is therefore considered irreversible when the helix angle of the inner gears is less than the friction angle

Having identified the type of gearbox to be used for the mechanics, in addition to the data required to dimension the Tracker's mechanical structure, it is very important to check the reduction ratio before purchase.

The reduction ratio is indicated by the letter 'i'. It is always indicated on the gear unit's data plate. On foreign-made gearboxes, the reduction ratio may be indicated by the term "ratio".

By sizing these components appropriately, good performance in terms of mechanical robustness and tracking accuracy will be achieved.

4.1 Reduction ratios

In this chapter, only the movement of the Azimuth axis is taken as an example, as the reasoning and calculations for the Elevation axis are exactly the same.

At the design stage, it must therefore be considered that:

- The gears that move the Tracker's mechanical structure must not be subject to reversibility phenomena.
- A high-performance solar tracker must have high tracking accuracy.

A good design requires a significantly high reduction ratio. However, as already mentioned, finding gearboxes with very high reduction ratios can be difficult. Let us see how to deal with this problem in a simple way.

Consider the possibility of using two gearboxes designed with mechanical characteristics that allow them to be coupled together

- First gearbox: reduction ratio i = 100
- Second gearbox: reduction ratio i = 100

The total reduction ratio obtained is the result of the product of the two ratios:

- Total reduction ratio: i = (100 x 100) = 10.000

Note: The higher the reduction ratio, the greater the positioning accuracy, while reducing the risk of reversibility.

4.2 Tracking resolution

Tracking resolution' refers to the ability of the system to track the Sun with a specific angular accuracy, i.e. the minimum angular position variation that the tracker is able to detect and compensate for in order to track the Sun optimally.

The smaller the angular value of the tracking resolution, the more precise the tracking will be. In summary, *'tracking resolution'* is an indicator of the system's ability to track the Sun accurately and responsively, optimising energy production

The controller automatically calculates the most accurate tracking resolution value on both axes depending on the reduction ratio used.

5. Construction of the mechanical structure

Once the type of mechanics to be adopted for the tracker has been determined, it must be appropriately dimensioned. When designing the mechanics, it is important to take into account the maximum excursion of the Sun during the summer solstice at the place of installation

Horizontal single-axis trackers or polar-axis trackers have a freedom of movement that usually does not exceed 90° or 120° of maximum total excursion, while two-axis models, due to their mechanical characteristics, can enjoy more angular excursion on their vertical axis (see photo on page 5).

The mechanical structure should be rigid and free of play, but in the design, it will be essential to take into account the thermal expansion of metallic materials

Taking into account normal mechanical wear and tear, wind loads and material deterioration processes, all Tracker components must be manufactured for a lifetime of no less than 20 years.

To guarantee a long service life, all steel parts of the structure must be protected against rust and oxidation. Hot-dip galvanising is an excellent solution.

Low-maintenance elementary components (e.g. sealed bearings and grease nipples) as well as simple but effective weather protection systems on motors and gearboxes will ensure the system's high reliability over time.

6. Safety overtravel

During the mechanical design, it is important to provide for the installation of a safety overtravel system. We recommend the use of electromechanical microswitches, which will interrupt the motor power supply in the event of a malfunction of the positioning system.

These devices must be of high quality and designed to operate in outdoor environments. During normal Tracker operation, they must never activate, making it essential to check their efficiency during scheduled maintenance.

They must be positioned within the Tracker's maximum angular excursion limit, in order to reduce the risk of damage to the structure in the event of improper handling in manual mode.

7. Installation and Tracker Orientation

In order to install a solar tracker, it is essential to have an open, shadow-free space. In the case of multiple installations, it is essential to check the distance between the units to avoid reciprocal shading during the course of the day and during the various seasons.

During installation, the orientation procedure takes place in automatic motion. Once the system is started up and the zero position, corresponding to the local solar noon, is acquired, the Tracker will autonomously position itself towards the Sun.

Note: Local solar noon is the time of day when the Sun reaches its highest elevation in the sky.

It is essential to know that:

- ***In the Northern Hemisphere at local solar noon the tracker is oriented SOUTH***
- ***In the Southern Hemisphere at local solar noon the tracker is oriented NORTH***

8. Tracker Maintenance

Proper maintenance includes a periodic check of moving mechanical parts and greasing of those parts that require it.

The check also aims to verify the correct tightening of the main bolts, the proper functioning of the aiming system and the main electromechanical components.

Maintenance must be carried out by authorised personnel with proven electromechanical experience.