Tap The Sun

The SolarTrak®
Controller System

Pro-Active Sun Tracking and Peripheral System Control

Designed and Manufactured by

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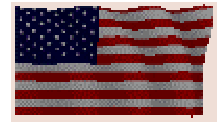


Made in the U.S.A

www.tapthesun.com

Operational Overview and Nomenclature

A solar tracker is an outdoor electro-mechanical device that follows the Sun's relative motion throughout the day, which is to say, it moves! Deliberately! It is a structural system that supports weight and resists external forces such as wind but unlike a building rigidly attached to the ground, it has pivots (axes [plural of axis] of rotation or hinges) and motors (or pistons) to allow the controlled motion of a solar energy collection system (collector or array) riding on a fixed support that is usually a central tower or pair of posts.

The SolarTrak® Controller uses mathematical computation for the Sun's position in the sky and counts electronic pulses (feedback) to determine the actual array (moving part of the solar tracker) position. By making these two positions coincide on a continuous basis throughout the day it will cause the array to follow the Sun.

This type of controller is not aware of clouds or other light distortions and in fact makes no distinction as to whether the Sun is actually visible to the eye. Although this method would seem to waste energy, since the unit will track on cloudy days when there is little available energy, sun sensors that detect the hot spot of the Sun will also often detect the bright edges of moving clouds (lensing effect), following them intermittently then moving back to the Sun, and can even lock on to strong reflections such as those pesky ones that bounce off of a parked-car windshield or, more often, the shiny surface of another tracker. Such distractions which are indistinguishable from the actual Sun by most electronic sensor circuitry, can cause an almost constant motion of the motors while hunting for the hottest part of the sky and actually use high levels of power (full motor current) all day long where the normal assumption is that the array only moves (updates position) once in a while and then only briefly.

The SolarTrak® Controller is designed around a digital microcontroller. The controller computes the local celestial bearing of the Sun with respect to the Earth by applying a published set of equations to characterize the motion of the Earth with respect to the Sun to within 0.01 degrees using the **Local Time, Date, Latitude, Longitude and Time Zone**. A battery-backed, temperature-compensated, on-board real-time clock supplies the time and date while the other system-defining parameters are stored in non-volatile (won't go away when the power goes off) memory within the microcontroller itself. Upon completion of the final calibration procedures, the clock will keep time to within fifteen seconds per year without attention. The tracking accuracy, depending on structural and electronic feedback characteristics, can be maintained to within 0.02 degrees.

The microcontroller is able to detect both digital (high, 5 Volts, or low, zero Volts, referred to as voltage states) and analog (variable voltage) signals, use the information to make comparisons or logical decisions and then exert necessary control over external devices.

The real-time clock offers the option of time-based peripheral (external device) task scheduling, in addition to providing the basis for this computational tracking approach, and sun-angle-based scheduling such as **Night Stow** where the array moves to an overnight, parked position when the Sun reaches a specified angle (such as setting) and wakes up when the Sun rises back to that angle.

The use of mathematics rather than direct sensing as the basis for pointing the array offers flexibility in the controller's response to the position of the Sun.

- It can, with great dependability, point something directly at the Sun.
- It can position a mirror to reflect a sunbeam to a fixed target.
- It can intentionally miss the Sun, preventing accidental focusing of concentrators while parked.
- It can prevent the shading of adjacent flatplate photovoltaic arrays with the application of a counter-Sun-motion control algorithm known as 'Backtracking'.
- It can systematically shade direct sunlight from passing through a skylight or window while allowing the maximum ambient light.
- The equations for the Sun can be replaced by equations for the Moon to drive a moon-bounce radio antenna or track the Sun during the day and the Moon at night for lighting systems.
- It can ignore the Sun altogether and perform other tasks required by the system on a scheduled or necessary basis.

Environmental Monitoring

For purposes of safety and damage avoidance control, the SolarTrak® Controller continuously monitors wind conditions and system power supply levels to allow a timely move to a less vulnerable emergency stow orientation before damage can occur.

It can be programmed to monitor and control related peripheral equipment associated with the tracking process including, but not limited to multiple slew (motion) rates, thermal protection (off-axis tracking), flow-rate control valves and pressure levels. There is a complete hydraulic control version that includes two-piston commutation on the primary axis and emergency control on a low-oil condition.

The controller will respond to external conditions by activating or deactivating devices or by causing the array to move off-sun (defocus). The auxiliary control of devices such as cooling fans or water valves can be laced into the tracking process to produce a seamless interaction between the sun-tracking and higher level functions.

The Standard Tracking Algorithm

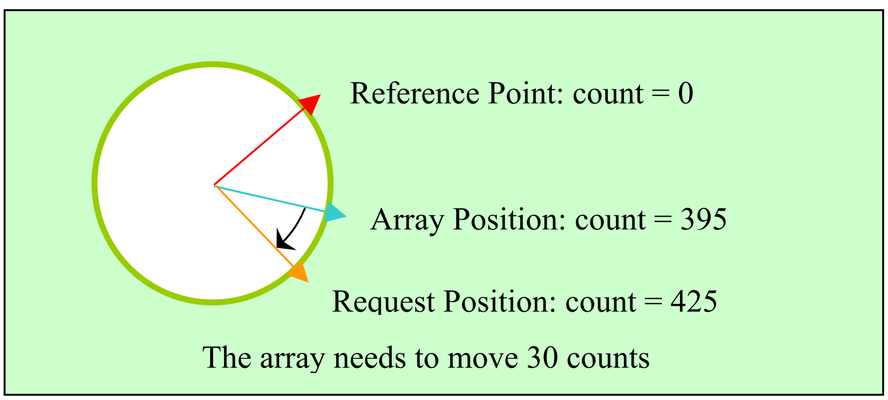
Because the controller does not sense the Sun with optical receptors, it needs to establish a different sort of reference to equate a particular computed angle with a particular mechanical orientation.

The position of the mechanical system is represented numerically as an offset (measured in counts) from a specific physical reference point. A sensor or other type of device generating an electronic pulse may define that reference point or it may be found by reaching a limit switch that interrupts power to the motor and stops the flow of electronic pulses, a detectable, 'stalled' state. In the case of absolute encoders (the former being incremental), the reference is implicit in the positioning of the device on the moving structure at installation. This also holds true for the positioning of the reference pulse generator for an incremental reporting system.

*** NOTE: **It is an absolute requirement that the Reference Point not move with respect to the related mechanical structure and that the count pulse-generator rate not vary with respect to position.**

Repeatability is EVERYTHING.

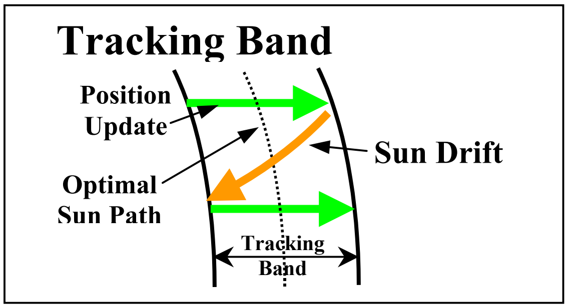
The central function of the tracking control process is to make the computed angle (**Request Position**) and the actual orientation of the mechanical system (**Array Position**) coincide.



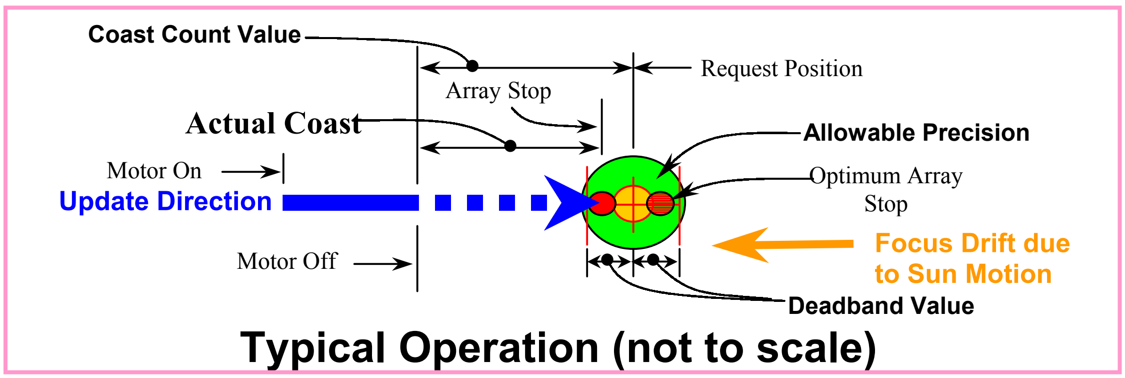
Request Position

The current sun position is recomputed unceasingly. Once one computation is complete another is begun. When a comparison of the reported (Actual) mechanical position is different from the computed (Requested) sun position the controller causes the mechanism to move until the two are once again the same. This 'sameness' can be based on 'fuzzy logic' defined by a 'deadband' centered about the requested sun position.

The 'Tracking Band' is the envelope of the array focal-line path resulting from the zigzag motion implicit in a periodic position update. 'Tracking' is accomplished by waiting until the focal-line drifts (due to relative motion of the Sun) out of the deadband then moving the array (updating) past the Sun, then waiting some more and updating the position again.



When the Array Position drifts outside the deadband window, the controller turns on the motor (or hydraulic valve) until the position is 'coast counts' away from the Request Position. The Coast Counts parameter allows for system momentum to carry the array further than the motor turn-off point without drastically overshooting the Request Position. The following illustration shows the various values but is not to scale. The motor actually turns on the moment the array position is one turncount outside the window.



A comparison between the sun angle and the array position is performed by converting the sun angle to array position coordinates (counts) using an equation involving **Gear Ratio**, defined here as **Counts per Radian** (radian = angular arc / radius of arc) then adding in a **Reference Offset** (in counts also) from a fixed zero point established by a **Reference Point** (**RP**) indicating where in the mechanical range of motion a particular count number occurs such that:

Request Position (counts) = **Sun Angle** (radians) * **Gear Ratio** (counts/radian) + **Reference Offset** (counts)