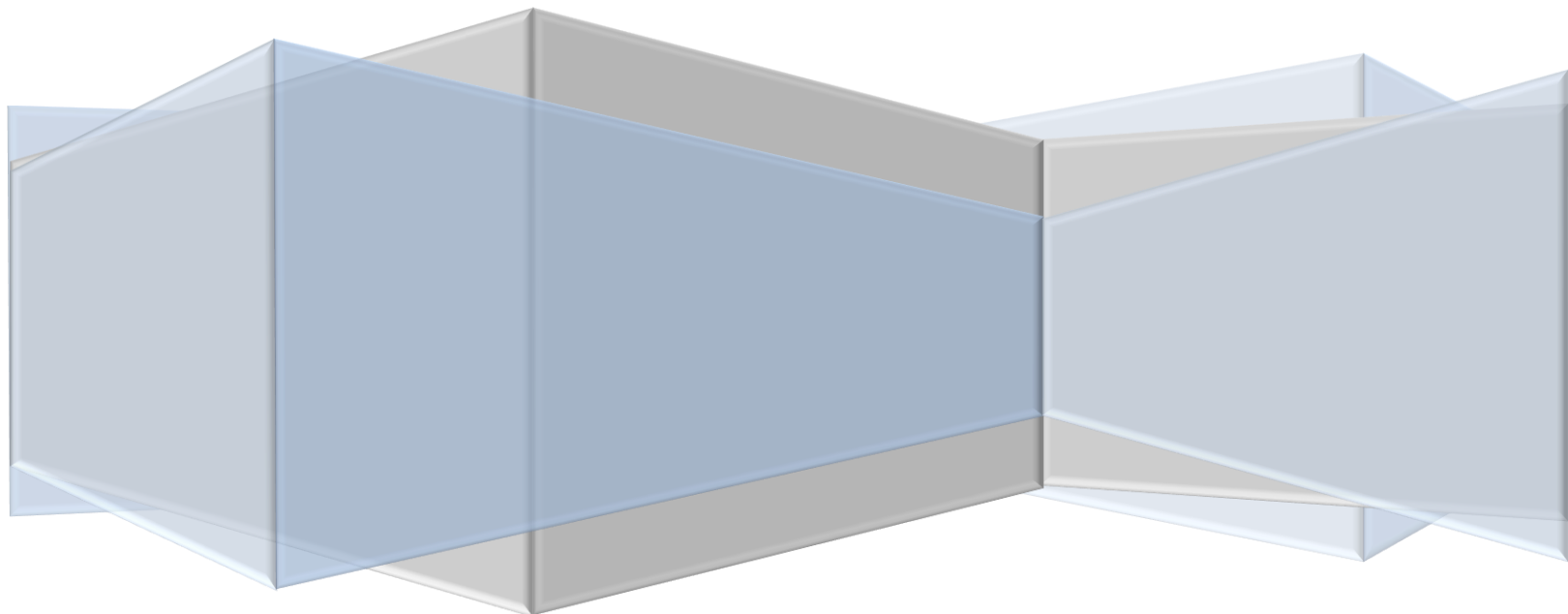




# Commissioning and Calibration of xCX/xDX Controllers

Rev 1.2, April - 2020



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## 1. Introduction

The purpose of this application note is to illustrate the commissioning and calibration of Lauritzen xxCX and xxDX solar tracker control systems.

**IMPORTANT; ONCE A SYSTEM HAS BEEN PROPERLY CALIBRATED, ADDITIONAL CALIBRATION MUST NOT BE DONE UNLESS CHANGES ARE MADE TO LIMIT SWITCHES OR OTHER SENSORS.**

## 2. Theory of Tracker Positioning and Target Finder

All solar tracker positioning is based on NREL's solar elevation and azimuth algorithm. The algorithm will correctly calculate the solar position from year 2000 to 2050, assuming the proper local geographic location and time of day is configured. A target Finder module is used to convert the solar target, as calculated by the solar algorithm, into actuator move commands dispatched to the Servo module.

For a given axis, the Target Finder must be informed of the conversion function, and related parameters, in addition to absolute reference points. The Target finder supports the following calculation methods;

- 1) Feedback from external inclinometer for elevation commands, positive and negative axis
- 2) Proportional (linear) relationship between actuator encoder feedback and tracker position
- 3) Positive (and negative) kinematic (triangular) relationship between (linear) actuator and tracker position
- 4) La Grange interpolation of relationship between actuator and tracker position

When the Target Finder is using an actuator's encoder feedback to calculate angle, two conditions must be met before the Target Finder correctly can calculate the target;

- 1) Encoder counter must be valid. This is done by moving actuator onto a prior established extreme limit such as an Eastern or upper limit.
- 2) Angular definition of reference point must be established.

When a solar tracker controller is powered-up, the encoder-counter is in an unknown state, and must be initialized. To do so, an actuator is moved against its absolute reference point/limit switch, such as the Eastern or upper limit, until the actuator has stopped AND the controller has acknowledged the presence of the limit switch. At that time, the controller will clear the encoder-counter and indicate it being valid for operation. To move the tracker against the Eastern or upper limit switch, either the push buttons, "srvgoto0 (az/el)" command, or the Heimdal iPhone application can be used. Note; if the tracker is moving in the opposite direction (e.g. West), the motor polarity can be switched in the "mtr\_polarity" field of the TrackerParam" field.

For more details about the angular definition of the reference point/limit switch, see the Calibration section.

## 2.1. Target Finder and Tracker Orientation

The purpose of the Target Finder is to convert a trackers angular direction into

- 1) Using encoder counter: an encoder counter target value
- 2) Using inclinometer: an inclinometer offset value.

In most applications, the encoder counter is used to position the tracker. This is accomplished by defining an absolute zero for the counter, which is found by driving the tracker to its “home position”. The Home position is typically the eastern and/or upper limit switch. The Target Finder will associate the limit switch with an absolute angular offset, and through its kinematic equations is thus capable of converting an angular target into an encoder counter value.

## 2.2. Target Finder and External Inclinometer

An external inclinometer can be used to provide a solar trackers elevation feedback. With such an arrangement, the target finder is responsible for

- 1) defining the relationship between the inclinometers horizontal versus solar trackers horizontal position
- 2) converting solar tracker’s elevation target to inclinometer’s elevation target

For more information about establishing the inclinometer to tracker relationship, see the Calibration section.

## 2.3. Target Finder and Proportional Encoder Feedback

An actuator’s encoder is typically used to govern the actuators motion but can also be used for positional feedback when combined with an absolute reference point. An actuator such as a slewing drive provides a linear relationship between the angular movements versus encoder feedback. Before the Target Finder can calculate the correct angle, the following items must be defined;

- 1) define encoder clicks-per-180 (*CP180*) degrees
- 2) encoder-count must be valid
- 3) actuator limit/reference point must be valid

The *CP180* value is best determined through a controller’s telnet interface. Assume we are interested in determining the *CP180* value for the azimuth drive. In that case we want to reset

the azimuth encoder counter with the servo command “`srvgoto0 az`”, followed by moving the actuator exactly 180 degrees by use of the manual push buttons – or by moving the actuator with “`srvgoto az (dest-in-clicks)`” command. Once the actuator has been moved 180 degrees, the encoder value can be read with the command “`encshow`”, and the CP180 value is transferred to the “`az_cp180`” parameter in the TrackerParameter setup page. Please see the Calibration section for details about how the reference point is defined.

## 2.4. Target Finder and Kinematic Equation

A Kinematic equation is used to compute the angle a linear actuator is producing as it forms a triangular shape together with two opposing fixed length segments ( $l_1$ ,  $l_2$ ). For the Target Finder to correctly calculate the angle, the following items must be defined;

- 1) define clicks-per-unit (*CPU*) of linear actuator extension
- 2) define triangle-to-tracker angular offset  $P_1$
- 3) define  $P_2 = (l_1^2 + l_2^2)$
- 4) define  $P_3 = (2 * l_1 * l_2)$
- 5) encoder-count must be valid
- 6) actuator limit/reference point (retracted actuator) must be valid

The *CPU* value is best determined through a controller’s telnet interface. Assume we are interested in determining the *CPU* value for the elevation drive. In that case we want to reset the elevation encoder counter with the servo command “`srvgoto0 el`”, followed by extending the actuator to its maximum length by use of the manual push buttons – or by moving the actuator with “`srvgoto el (dest-in-clicks)`” command. Once the actuator has been moved, the encoder value can be read with the command “`encshow`”, and the  $CPU = (\text{encoder\_counter\_value} / \text{delta\_extension})$ .

Please contact Lauritzen for how to calculate  $P_1$ . Please see the Calibration section for details about how the kinematic mode is defined.

### 3. Target Finder Calibration

**IMPORTANT; ONCE A SYSTEM HAS BEEN PROPERLY CALIBRATED, ADDITIONAL CALIBRATION MUST NOT BE DONE UNLESS CHANGES ARE MADE TO LIMIT SWITCHES OR OTHER SENSORS.**

**IMPORTANT;** for a solar tracker axis with encoder feedback, the controller must have a valid set of encoder counters. To reset the encoder counters, the tracker must be moved against its home position. The home position is defined as the eastern limit, upper (horizontal) limit, or retracted limit. The preferred method for moving to a home position is to use the telnet command *srvgoto0 (az,el)*, or simultaneous push the East/West or Up/Down buttons.

Another method to clear the encoder counter is to let exit Service Mode, and let the controller move the tracker to the limit switch(es).

**IMPORTANT;** for systems using timed feedback, see [Calibration for Tracker Axis using Timed Feedback](#).

#### 3.1. On-Sun Calibration

If the sun is sufficiently above the horizon to allow the tracker to be moved directly onto the sun, while in SM, move tracker so that it is exactly facing the sun. At this time, the CAL button is depressed for about 2-3 seconds, until the APP,COMM and SYS LED's flash in unison. **The controller is now in Calibration Mode (CM).**

Note; if Calibration Mode (CM) is accidentally entered, it can be gracefully exited by depressing and releasing the Reset button.

With the tracker facing the sun, and in CM, the CAL button is depressed and release. A calibration-on-sun procedure has now been performed.

#### 3.2. Dual-Axis; Off-Sun Calibration

If the sun is not present during calibration, the eastern and horizontal directions can be used as a substitute. While in ServiceMode mode, drive the tracker so that it is facing due south. For the southern hemisphere, the tracker is driven to due north. Now enter CalibrationMode followed by depressing the West button. Similarly, with the elevator; drive the tracker to horizontal, and enter CM followed by depressing and releasing the Down button. Now exit SM, and controller will assume operational status.

### **3.3. Single-Axis; Off-Sun Calibration**

In the case of single-axis trackers, the easiest calibration method is to, while in ServiceMode, move the tracker to horizontal. Now enter CalibrationMode, followed by depressing and releasing the Up (or Down) button. Exit SM, and controller will assume operational status.

### **3.4. Dual-Axis Synchronous Offset Calibration (Envision Solar)**

After the tracker has been through basic Calibration (see above), the two actuators may now be locked into a specified offset. While in SM, move the actuators with the manual push buttons until desired actuator offset. To lock-down the desired offset, enter Calibration Mode (CM), followed by depressing either the Up or Down buttons. Now exit SM, and the SCX will assume normal operations.

### **3.5. Calibration for Tracker Dual-Axis using Time Control**

Timer Control (TC) method can be used as an encoder substitute for the azimuth drive. Calibration of TC azimuth axis can be done with push buttons or via telnet commands. With push buttons, it is mandatory to have clear skies for an entire day. With telnet commands, eastern and southern (in southern hemisphere – northern) directions must be known.

The azimuth axis is first reset; while in SM, push both East/West buttons simultaneously and release. The tracker will now move east until eastern-limit switch. With the tracker at the eastern limit switch, and using the West button, the tracker is moved in steps until it faces the sun. One West button push will move the tracker one timed step – typically 5 seconds. Do NOT queue West move commands. Wait until motor has come to a complete stop before issuing another west move.

A minimum of two calibration points is required for azimuth operation. Note; a third and fourth can be used to improve calibration. The calibration points should ideally be spaced a minimum of two hours apart.

To perform a calibration point (CP), the tracker is moved to face the sun using the East or West move buttons while in Service Mode. Calibration Mode is entered by depressing the CAL button for two seconds. Once in CM, push the East button and release. Wait a minimum of two hours and enter another CP. With two CP's, SM may be exited, and the is operational. Additional CP's can be entered by placing the tracker in SM, adjust tracker with West button, or wait, until tracker is facing sun, then enter a CP.

Calibration may also be performed via telnet commands as follows

- 1) Enter *svrgoto0 az* to move tracker against eastern limit switch.
- 2) Using *svrgoto az (n)*, where *n* is number of timed steps, tracker is moved to face east.
- 3) Enter command *callim az 90.0* to issue first calibration point.
- 4) Using *svrgoto az (n)*, where *n* is number of timed steps, tracker is moved to face south.
- 5) Enter command *callim az 180.0* to issue second calibration point.

#### 4. SCX Telnet Commands during Calibration

The PC/Unix application telnet can be used to control the SCX during calibration. Please see separate *Telnet Interface* document for basic telnet setup and usage. The following table contains the commands most often used during calibration:

| Servo Command                | Description  |
|------------------------------|--|
| <i>svrgoto0 (az/el)</i>      | Force either azimuth or elevation encoder to be reset. Servo will start motor and move toward eastern or upper limit switch. For example; <i>svrgoto0 az</i> will reset azimuth encoder.         |
| <i>svrgoto (az/el) (tgt)</i> | Request servo to move azimuth or elevation motor to the <i>tgt</i> number of encoder clicks. For example; <i>svrgoto az 334</i> will move the azimuth motor to the encoder-counter value of 334. |
| <i>svrhalt</i>               | Stop motor operation   |
| <i>encshow</i>               | Display details of encoder counter and encoder operation   |

| Target Finder Command        | Description   |
|------------------------------|---|
| <i>tgtshow</i>               | Display operational details of the target finder  |
| <i>tgtgoto (az/el) (tgt)</i> | Dispatch move request to a given angular position, where the position is in 1/100'th of degrees (DEC100). For example; <i>tgtgoto el 356</i> will dispatch the servo to move the elevation motor to the angular offset of 3.56 degrees. Note; on newer software versions, the target is specified in decimal notation rather than DEC100. Use <i>tgtgoto -h</i> to determine which is used. |
| <i>callim (az/el) (tgt)</i>  | Calibrate azimuth or elevation limit according to the current tracker direction as specified by the <i>tgt</i> position, where the target position is specified in 1/100'th of a degree (DEC100). Note; on newer software versions, the target is specified in decimal notation rather than DEC100. Use <i>callim -h</i> to determine which is used.  |



|        |  |
|--------|--|
| calsun | Assuming tracker is pointed at sun, calibrate both azimuth and elevation limits. |
|--------|--|

| Other commands | Description  |
|----------------|--|
| halt           | Stop motors immediately and shutdown tracker operation |
| info           | Display basic information about controller             |
| service (0/1)  | Set service or clear tracker service mode              |
| trkrun         | Start automatic tracker operations                     |
| trkshow        | Display tracker operational details                    |

## 5. Possible Controller Errors during Calibration & Operation

When a solar tracker controller is commissioned, it is not uncommon to discover wiring mistakes. This section will briefly discuss the most basic error codes as displayed by a controller's Application LED and the underlying cause. Once a controller has entered an error state, it must be reset before additional operation can take place. The following table defines the Application LED Error codes, and how to resolve them;

| Code# | Legend      | Definition   | Resolution  |
|-------|-------------|--|---|
| 1     | Stop        | Stop switch is engaged   | Release Stop switch                                 |
| 2     | Servo Fault | Motor drawing current, but encoder signal is absent                        | Check encoder and encoder wiring                    |
| 3     | AB Check    | A or B signal of dual channel encoder is absent                            | Check encoder and encoder wiring.                   |
| 4     | AB_Crossed  | A/B signals of dual channel encoder have been crossed                      | Operate actuator for > 10 sec while in Service Mode |
| 5     | Stuck Limit | Limit switch remains closed after tracker has moved away from limit switch | Check limit switch                                  |
| 6     | Run Away    | Encoder movement is seen while motor power is absent                       | Check encoder wiring for loose connection           |
| 7     | ANM Failure | Anemometer Failure/no signal for extended period                           | Check anemometer and wiring                         |

| <b>Code#</b> | <b>Legend</b>        | <b>Definition</b>   | <b>Resolution</b>  |
|--------------|----------------------|---|--|
| 8            | Sync Failure         | Dual azimuth drives have become unlocked                        | Check motor power and encoder wiring. Restart controller and align drives singularly before resuming automatic operation   |
| 9            | No Motor             | A disconnected motor has been detected                          | Check motor power LED's (adjacent to MEL/MAZ terminal connections) while in SM and using move-push-buttons. If LED's are working, check motor wiring and/or motor. |
| 10           | Anemometer Failure   | Anemometer pulses have not been detected for specified timeout. | Check AN LED for anemometer pulses. Test anemometer input by connecting wire to AN and NEG.  |
| 11           | Inclinometer Failure | Unexpected data from inclinometer                               | This error will happen if inclinometer experiences rapid movements – inconsistent with normal tracker operations.  |
| 12           | Stuck Inclinometer   | Inclinometer failed to move                                     | Controller attempted to move tracker, but did not find inclinometer to move.   |

## 6. Revision History

| Revision | Release Date   | Comments/Changes   |
|----------|----------------|--|
| V1.0     |                | Initial release.   |
| V1.1     | October-9-2019 | 1) Removed references to old iPhone app<br>2) Added calibration for timed azimuth control. |
| V1.2     | April-1-2020   |  |

## 7. Contact and Support

Please contact tracker installer for support and warranty issues.

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