OPERATING AND INSTRUCTION MANUAL FOR SINGLE AXIS SOLAR TRACKER CONTROLLER (WITH BACKTRACKING)

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Specifications:

1. Tracker principle:	controls azimuth angle according to astronomical sun positioning
2. Tracking axis:	single axis
3. Backtracking:	available for single axis horizontal plane.
4. Size:	170mm x 120mm
5. Input voltage:	230V AC,50Hz +/-15%
6. Enclosure:	IP65 ABS grade.
7. Termination:	IP65 graded ABS glands – 3 nos.
8. Output:	Potential free contacts for Forward and reverse to VFD
9. Resolution:	0.1 degrees.
10. Axis angle:	settable up to +/- 60 degrees.
11. Min. Operating voltage:	15V DC
12. Control action:	automatic closed loop using inbuilt inclinometer for angle feedback
13. Display:	16 x2 alphanumeric LCD display
14. Timing:	Inbuilt using highly accurate RTC with independent battery backup.
15. Accuracy:	less than +/- 1 degree error for range +/-60.0 degrees.
16. Safety features:	a. Reverse polarity protection for unit b. Voltage spike suppression.

* Note that the unit will continuously monitor the angle of the unit every 20 seconds during panel movement to ensure that the actuator is working properly. If the angle of the panel/unit has not changed even when the actuator is ON for more than 2minutes, the unit will assume there is some mechanical fault in the system and automatically turn OFF the output to the actuator and wait for the next cycle.

Principle of operation:

The single axis tracker is based on an internal dynamic calculation of the solar sunrise and sunset time using the current real-time and date from its inbuilt RTC. After this data is achieved, it first calculates the sun angle, then calculates the target angle of the panel (different from sun angle if backtracking is required) and finally controls the actuator load to achieve this angle. This control action is repeated for every specific time interval from sunrise to sunset. Note that this unit does not depend on the time the actuator is ON or take positional feedback from it,but instead takes positional feedback directly from the unit mounted and tends to turn the panel to the correct angle. This ensures that even if there is any deviation of the panel angle at any point of time due to external intervention OR through the manual mode of the unit, the unit will recover the panel automatically in the next control cycle. The LCD display shows the various important parameters like Time, Date, Target -angle/Target time,etc.(discussed in the next section). The unit also provides setting of various parameters to the user through four keys on the front panel thus making the unit extremely flexible and can be adapted by the user for different environments much easily.

Programming modes of the unit.

The Programming keys are inside the unit and the cover needs to be removed to access/change the different parameters of the unit.

1. Normal mode: (Read only)

This is the default display mode of the unit on power ON. It scrolls the following sets of important data to the user to confirm the proper functioning of the unit.

a. Real- time and present angle for 35 seconds.
b. Sunrise and sunset time for 10 seconds.
c. Next target angle and time for 10 seconds
d. Current date and Start/End angle for 10 seconds.
e. Back to a.

2. Manual mode:

To enter this mode, press and hold SHF (A/M) key for 8~ 9 seconds. The display will initially show "Manual mode entering…" for 2 seconds and then continuously show the actual angle of the panel in the bottom row. Now the user can manually inch the panel in the forward OR reverse direction by pressing the DEC and INC key respectively. To exit this mode, just press and hold SHF key again for 3-4 seconds until the message "manual mode exiting…" pops on the display.
This mode is recommended only during installation or general troubleshooting of the mechanical structure of the panel and unit should be exited to the normal mode once work is over.

3. Program mode:

This mode is used for setting the various system parameters of the unit like time, date, time interval, etc.
To enter this mode, press and hold SET key for 3-4 seconds. To change the parameters, use the SHF key to move highlight (blinking) within the parameter and then to increment /decrement the value of the blinking value, press INC and DEC key. To save the present parameter and move to the next parameter just press momentarily the SET key again. The various parameters and their functions are as below:

a. "**Set Date**": This is the current date of the unit in dd-mm-yyyy format
b. "**Set Latitude**": This parameter is the Latitude of the location of installation of the solar tracking system.
c. "**Set Longitude**": This parameter is the Longitude of the location of installation of the solar tracking system.
d. "T**ime Interval**": This determines the periodic time interval in minutes during daytime
When the unit recalculates the next target angle/ target time and tends to bring the panel to the present required angle. This parameter increment in steps of 5 minutes from 15 to 90 minutes.
e. "**Set Timezone**": The timezone of the region of installation (e.g.GMT+5.5 for India).
f. **"Set Time"** : This is the current real time of the unit in hh:mm:ss format. Note that it is the standard time of the region and should be set accordingly.
To come out of the Program mode, press and hold SET key again for 3-4 seconds. The unit will revert back to the normal mode.
f. **"Set Panel Width"** : This is the total width of the panel in meters to be inputted by the user. Used by the unit for calculating backtracking ratio along with the distance between panels
f. **"Set Distance"** : This is the center to center distance between the panel arrays in meters to be inputted by the user. Used by the unit for calculating backtracking ratio along with the panel width.
To come out of the Program mode, press and hold SET key again for 3-4 seconds. The unit will revert back to the normal mode.

4. Installation mode(Setting the Start and End Angle Limits):

This mode is required for calibrating the start position and end position of the panel in sync with the unit. This ensures that the target angle to be achieved will not cross this limit while controlling the panel. To enter this mode, follow the following procedure:

Press and hold INC key for more than 10 seconds The display will show “Calibration Mode entering” on the display for 2-3 seconds and then show “set start angle “ and actual angle on the display. Now inch the panel to the start position using the **INC** or **DEC** key and press **SHF** key to accept the start angle. A confirmation will be momentarily displayed “start angle accepted!” on the display and the display will now show “set end angle”. Again move the panel to the required end angle using INC and DEC keys and press SET key to accept the end angle. A confirmation”end angle accepted!” will be displayed momentarily before the unit reverts back to the normal mode. Note that this mode is required only once during installation of the panel on site and need not be set again. The start /end angle setting ensures that the actuator is not pushed to its extreme ends.

The status of the Start /End Angles can be viewed in the normal mode.

Special modes of the unit.

NIGHT mode (Low Power mode):

This low power mode of the unit is a special mode initiated 30 minutes after sunset and is valid upto 30minutes before sunrise the next day. In this mode, the unit consumes upto 30% less current compared to the normal daytime active mode. The display will show “NIGHT MODE” and real time clock and the following parameters (not required during the period from sunset to sunrise.) are disabled:

1. Output to the actuator
2. Backlight to LCD and Other LED indications.

During this mode, if any key is pressed for more than 1 second, the unit will revert back *temporarily* to the active daytime mode. This ensures that the user can set the various parameters even in Night mode. If the unit does not receive any key response from the user for more than 30 seconds, the unit will revert back to the Night mode.

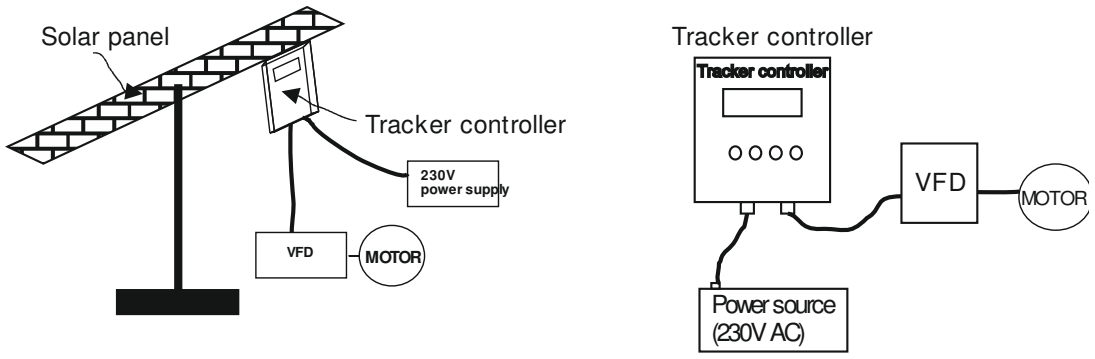
Solar Tracking System requirements:

A self contained simple single axis solar tracking system requires the following items:

1) Structure: A sturdy and light weight mechanical arrangement to carry the solar panels which can move freely along a single axis from east to west parallel to the ground plane.
2) Power supply: A single phase power supply of 230V AC to power the unit
3) VFD : An appropriate VFD to drive the motor used to move the panels
4) Motor: A motor with appropriate rating to connect to the VFD and suitable Arrangement to move the panels
5) Connecting Cables: Single core insulated copper cables with at least 2mm^2 cross section area.

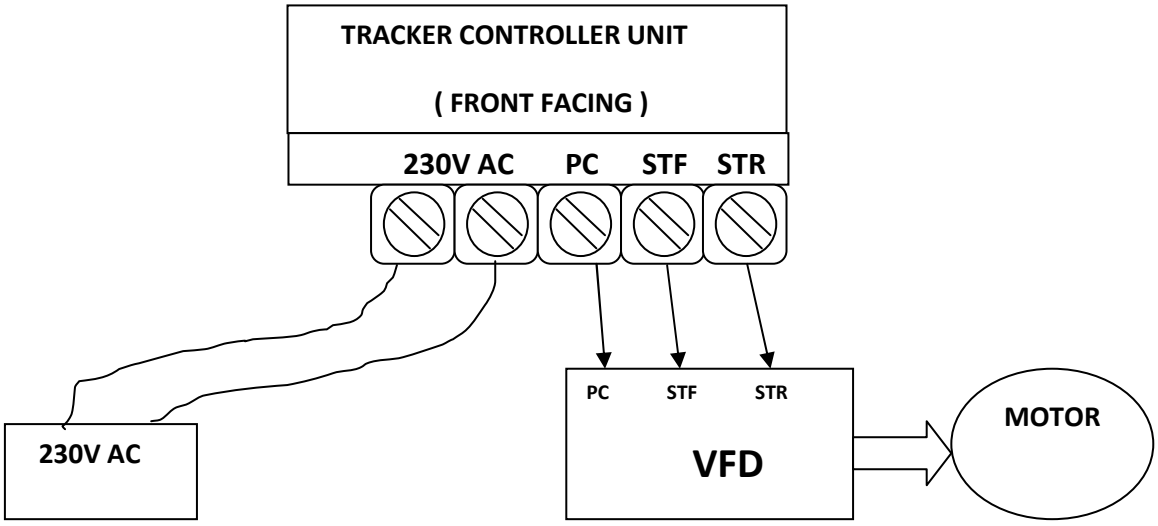
The figure below shows a typical solar tracking arrangement and connection diagram to the various components of a tracking system:

Fig.1



Internal connection details of unit:

The unit contains a 5 terminal connector for connecting the various inputs/outputs to the unit. The diagrammatic representation is as below:



Follow the following procedure while connecting the terminals:

1. Open the Box. Ensure that the ON/OFF switch near the terminal is in OFF position.
2. Now connect the Power Source 230VAC to the power terminals**.** Now turn the switch to ON position.
3. Once the unit is powered ON ,the display will start showing the default values. Turn OFF the switch and connect the PC,STF and STR terminals to the respective terminals on the VFD. It may be required to reverse the STF and STR terminals to the actuator depending upon the mounting arrangement of the actuator for a particular structure.

   To confirm the proper polarity, put the unit in the manual mode and press the DEC key to turn the actuator in forward *(FOR* led) direction. In this case if the Panel moves from the EAST to WEST direction, the termination is proper. If the Panel tends to move in the opposite direction, then reverse the polarity of the STF and STR connection.

Mounting the Tracker controller unit:

Once the Tracker controller unit settings have been inputted, the unit should be mounted on the moving arm of the panel as shown in fig. 1. Note that the front panel should be facing in the **southern** direction. Now connect the Power supply input to the power terminals and the PC,STF,STR to the VFD. As the inclination sensor is inbuilt in the tracker unit, ensure that the unit is mounted firmly and in parallel to the arm of the panel structure (as shown in fig.1).
Also ensure that the terminals are connected correctly to the various devices.

Setting the Tracker controller unit:

The target angle calculated by the unit depends upon the various settings of the unit like real time , date , latitude/longitude and the time zone of the region. So these parameters should be determined and inputted to the unit before installing the unit on the structure. A detailed explanation of the various parameters is cited below.

1. ***Date /Time:*** this parameter refers to the real time date and time of the region of installation. The time is shown in format hh:mm:ss and the date is shown in the format dd:mm:yyyy. ***Important: Note that the unit does not have any daytime adjustment provision. So adequate adjustments should be made to input the standard time/date without daytime correction when installing in specific countries where there is a daytime adjustment.***
2. ***Latitude:*** This parameter refers to the latitude of the location of installation. The range of setting would be +/- 90.00 degrees. Note that the sign of the latitude indicates whether the location is located north or south of the equator. +ve implies North and –ve value implies South of the equator. The latitude should be inputted in decimal form. So a value of say $76^{o}30'$ should be inputted as 76.50 degrees.
3. ***Longitude:*** This parameter refers to the longitude of the location of installation. The range of setting of this parameter is +/- 180.00 degrees. The sign of the longitude indicates whether the location is situated to East or West of the prime meridian (Greenwich meridian). +ve implies East of the meridian and –ve implies West of the meridian. Similar to latitude, the value is in decimal form and should be determined and inputted accordingly.
4. ***Timezone:*** This parameter refers to the time zone of the region of installation. It should be in relation to the Greenwich meridian Time (GMT). A positive value (e.g. GMT+5.50) refers to a location East to the prime meridian and a negative value (GMT – 7.00) refers to a region west of the prime meridian. These parameter increments in steps of 0.25Hrs i.e. 15 minutes.
5. ***Time interval:*** This parameter determines the periodic time interval in minutes during daytime when the unit recalculates the next target angle/ target time and tends to bring the panel to the present required angle. These parameter increments in steps of 5 minutes from 5 minutes to 90 minutes max. Note that lesser time interval leads to more accuracy but greater power consumption by the actuator and vice versa in case of a larger time interval.
6. ***Panel Width:*** This parameter should bear the width of the panel(W) as shown in figure2. This parameter determines the backtracking ratio of the solar array along with the distance between panels (D) and accordingly the target angle of the panel is calculated. The settable range is between 0.1meters and 99.9meters
7. ***Distance:*** This parameter should bear the centre to centre distance(D) between the panel arrays as shown in figure2. This parameter determines the backtracking ratio of the solar array along with the panel width (W) and accordingly the target angle of the panel is calculated. The settable range is between 0.1meters and 99.9meters

Backtracking :

A typical panel array arrangement for a solar power plant involves placing solar arrays back to back. This casts a shadow from the front array to the immediate back array during early morning and vice versa during late evening times. This results in a sharp drop in power output of the panels. To avoid this, the arrays alignment have to be compensated by using backtracking principle. This algorithm ensures that the shadow does not overlap the adjacent array and the panel target angle is calculated accordingly. The unit calculates if the backtracking is required and sets the target angle accordingly. If the backtracking is not required at certain sun angles, the target angle will follow the sun angle. A typical arrangement of panels is shown below.

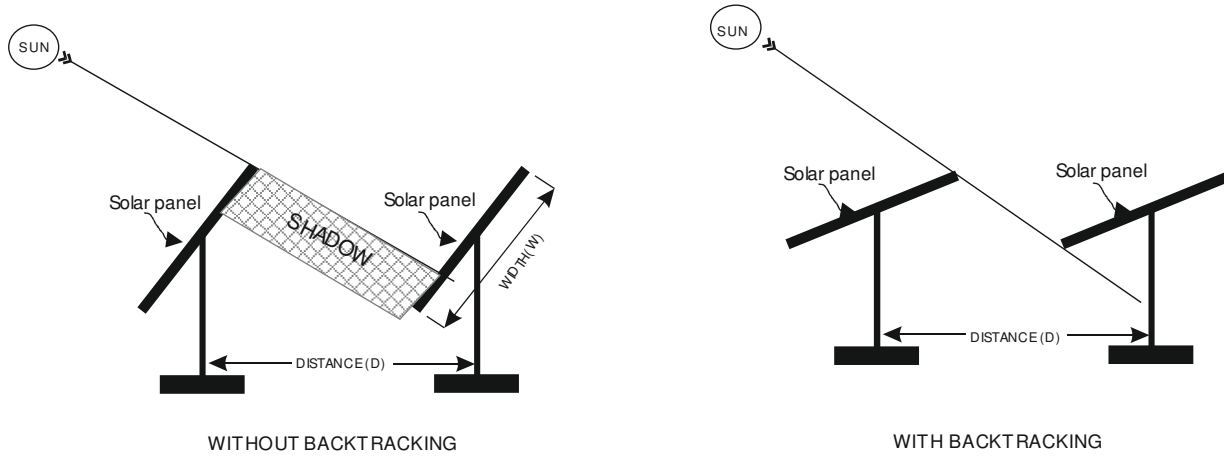


FIG.2

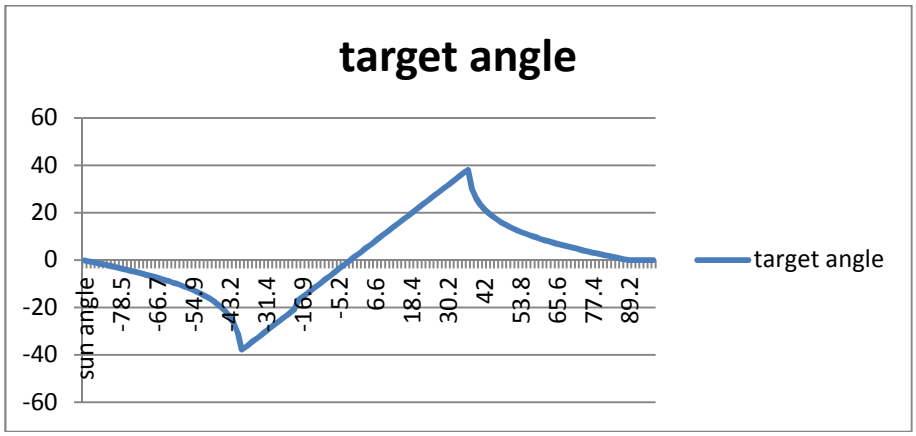
The panel typically starts at 0 degrees on sunrise (backtracking algorithm) and gradually tends towards east during morning. After a certain time(depending upon the backtracking ratio determined by the width and distance) , the panel will stop backtracking and follow the sun angle till a certain point in the evening where the backtracking is again required to prevent evening shadow. Now the panel slowly tends towards stow (0 degrees) position and reaches it at sunset. The cycle repeats for the next day.

<u>If the backtracking algorithm is not required for certain cases, the width should be set to min.value (0.1m) and the distance to the maximum value(99.9m).</u>

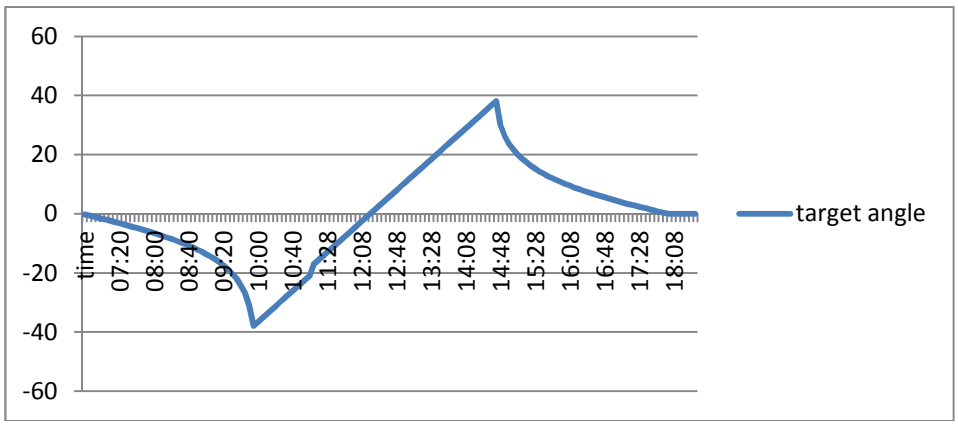
The next section will show a typical arrangement and graph of a solar array arrangement with a 1m width panel and different distances between panels of 1.3m and 1.7m respectively

Example 1: These graphs show the response of the tracker for an arrangement of panel width 1m and distance 1.3m. under the following conditions:

Date: 11-01-2022 Sunrise: 06:41 Sunset: 18:09 High Angle limit: +45.0 Low Angle Limit:-45.0

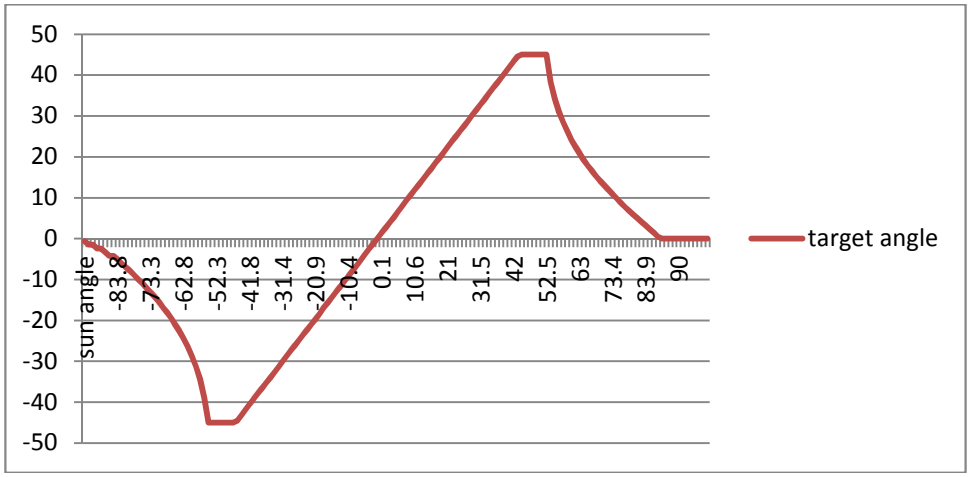


Target Angle v/s Sun angle

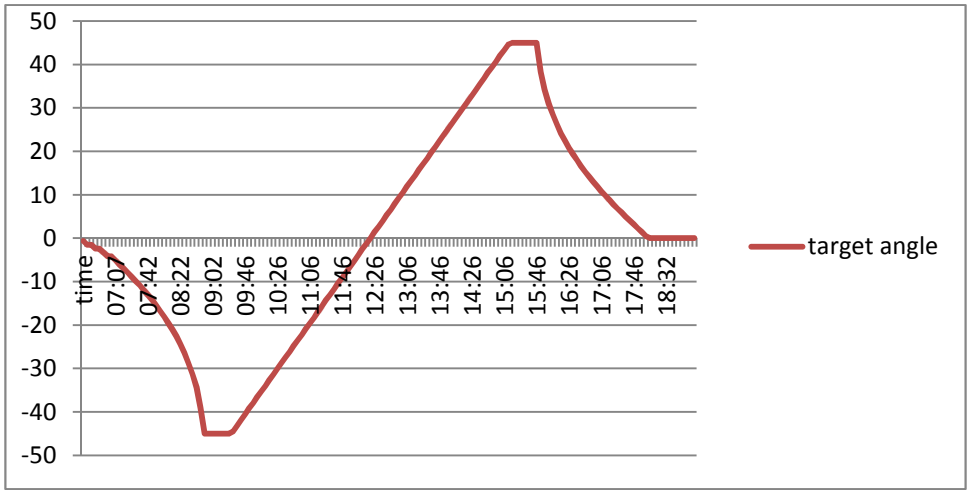


Target Angle vs Time

Example 2: These graphs show the response of the tracker for an arrangement of panel width 1m and distance 1.7m. under the following conditions:
Date: 11-01-2022 Sunrise: 06:41 Sunset: 18:09 High Angle limit: +45.0 Low Angle Limit:-45.0



Target Angle v/s Sun angle



Target Angle vs Time

Note that in this case as the calculated target angle exceeded the high and low limit (+/- 45.0 deg in this case) and the tracker clipped it to maintain the angle at the extreme ends preventing the system from crossing it and causing damage to the structure.

Troubleshooting:

Possible errors and checkings are as under:

Error indication	**Possible causes**	**Possible Solution**
Unit not showing display	1. Power supply not connected or loosely connected	Check Supply voltage on power terminals for loose connection.
No motor movement	1. Wrong settings on unit 2. VFD connection faulty	Check settings like date/time latitude/longitude and time zone on unit. Put unit in manual mode and check if VFD/Motor is working in forward/reverse direction.
Date/Time does not retain values on power reset	The internal RTC battery is faulty.	Remove the power connections to the unit. Now remove top cover and replace the internal CR2032 3V Li-ion Button cell. Replace the power connections and set the current real time/date from the front panel.

If the above solutions do not solve the problem, it is recommended to consult the vendor/manufacturer for further advice.

Precautions:

The unit has two cable gland entries provided on the bottom of the unit to reroute the connections of the two outputs shown above separately. Ensure that the glands are tightened securely before operating the unit.

As the unit will be mounted on a moving structure, it is recommended to ensure that the connections to the internal connector are secured tightly to avoid loose connection problems in the long run.

The unit being mounted on a moving structure, use appropriate mounting arrangement for the unit to avoid accidental loosening of the unit as that may provide a wrong angular positioning feedback to the unit.