UiT The Arctic University of Norway

Department of Electrical Engineering

Solar Angle Optimizer

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Preface

This master thesis explores the concept of solar angle optimization, a key aspect of harnessing solar energy efficiently. As the world grapples with the challenges posed by climate change and the increasing demand for sustainable energy sources, solar power has emerged as a promising solution. However, the efficiency of solar energy conversion heavily relies on the optimal positioning of solar panels to capture maximum sunlight.

The purpose of this thesis is to investigate and develop a solar angle optimizer, a novel approach that seeks to enhance solar panel performance by dynamically adjusting their tilt and orientation. By leveraging advanced technologies such as sensors, motors, and control algorithms, the solar angle optimizer aims to constantly adapt solar panel positions in response to varying sunlight conditions, thereby maximizing energy generation.

I was immediately drawn to this project since I love programming, and writing PLC code was one of the most important aspects of it. Working on this project taught me many new, practical things.

My heartiest gratitude to my supervisor, Trond Østrem, associate professor of UiT, Narvik, Department of Electrical Engineering, for his excellent guidance. Without his supervision this project would not be possible. He was always willing to help and was always there whenever I needed.

I want to express my gratitude to my family who made it possible for me to be where I am now, and for their unwavering encouragement.

22nd May 2023
Md Emranul Haque

Abstract

The demand for renewable energy sources has increased significantly in recent years due to the growing concerns about climate change and environmental sustainability. Solar energy has emerged as one of the most promising and widely used renewable energy sources. However, the efficiency and output of solar energy systems depend on various factors, including the position of the sun, the angle of the solar panel, and weather conditions.

A detailed design, method, and tested outcomes of a solar angle optimizer are presented in this master's thesis being the main focus. The primary accomplishment is the testing, simplification, and preparation of extensive documentation that can be used in future study on Photovoltaic system optimization. For this specificity, calculating the sun's position using an RTC module and positioning the PV panel perpendicular to the sun is not accomplished in this study.

As this thesis is the improvement of a previous master's thesis, some tests are done on prebuilt H Bridge-motor drive, Power measuring board and Programmable Logic Controller (PLC) codes. Moreover, all the flaws of previous designs and works are mitigated by designing and building new boards or some other alternative ways. All the sensors and equipment are connected to PLC and few PLC programs are developed for various tasks and tests.

Mainly, the code is developed for a motor control system that positions the Photovoltaic (PV) panel to an optimal position where the power output is maximum. And after optimization, in a certain interval, it positions itself accordingly, if the position of maximum output changes.

While building the whole system some safety issues are taken into consideration like storm and uncontrolled rotation of the rig. Codes are developed to prevent uncontrolled rotation and during storm the panels will be positioned horizontally to reduce air drag.

Several tests have been performed: The H bridge motor drive from previous work is tested but unfortunately it was not working so a new one is designed and built.
Power measuring board from previous work is tested and there were major design flaws. As there is limitation of time so some prebuilt devices are used to measure voltage and current of the PV panel, instead of making a new one.
Induction sensors has been tested if they can prevent the rig from hitting any obstacles. The 'Positional initialization of the PV panels using Induction sensors' is also tested.
Using a strong light source at UiT Electrical Machine lab, the performance of the whole system is observed at different conditions and the results are logged into PLC using a data logger program.

The lab tests were performed using only one PV panel for simplification, whereas in the final phase, it is effective for total 8 panels. With an open circuit voltage of 21.20 V and a peak power current of 2.94 A, each panel is capable of delivering 50 Watts of peak output.

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1 Introduction

The world is facing an energy crisis, and with the increasing concerns about climate change and the finite nature of fossil fuels, the need for sustainable and renewable energy sources has never been more pressing. Solar energy is one of the most promising and widely adopted alternatives to fossil fuels, as it is a clean, abundant, and sustainable source of power. However, to fully leverage the potential of solar energy, it is essential to optimize the performance of solar panels. One of the key factors that affect the performance of solar panels is the angle at which they are positioned. The angle of the solar panels can have a significant impact on the amount of energy they can capture from the sun, and finding the optimal angle is crucial for maximizing their efficiency. The solar angle optimizer is a device or a system that adjusts the angle of solar panels to optimize their efficiency in capturing energy from the sun. There are different ways to design such a device, depending on the specific application and the type of solar panels used. Lab test model is shown in Figure 1.

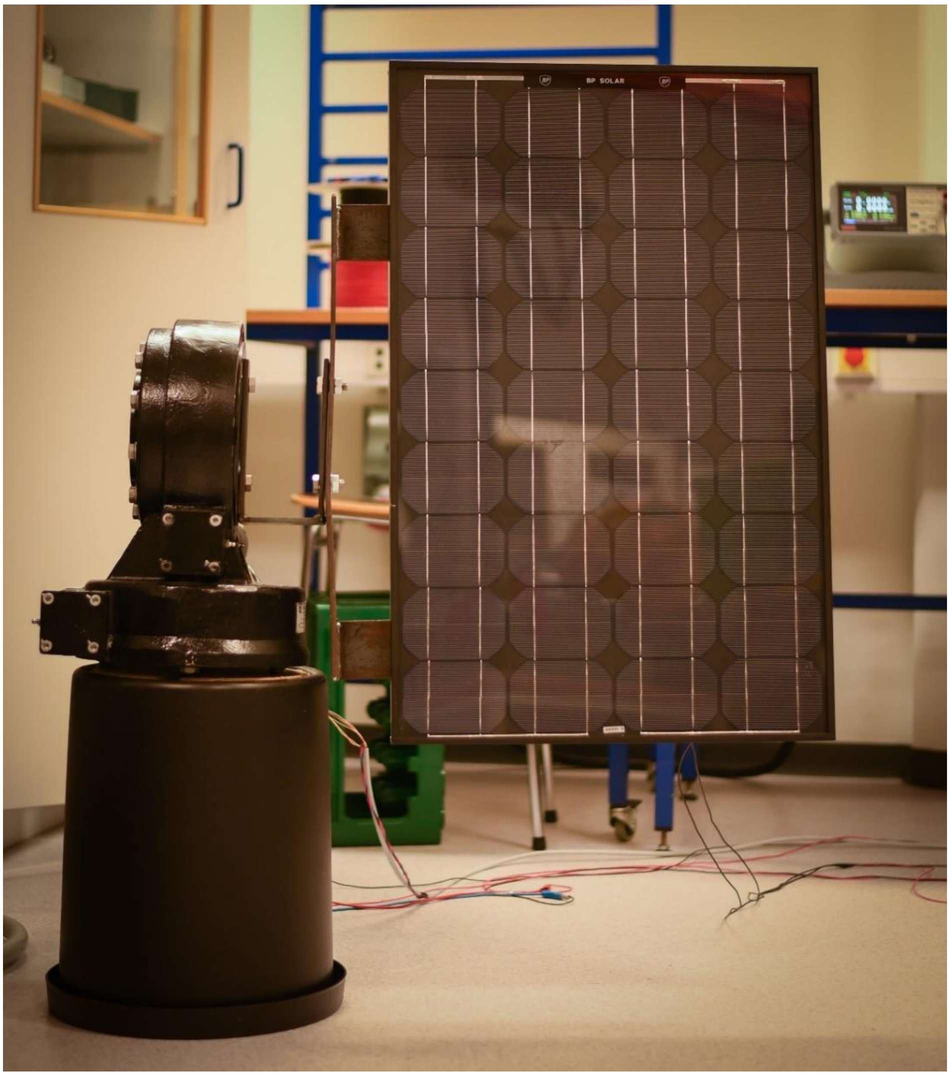


Figure 1: Dual axis solar angle optimizer (Lab test model)

The Solar angle optimizer can use different techniques such as using sensors to track the sun's movement or using weather forecast data to predict the sun's position, and automatically adjust the angle of the solar panels throughout the day to capture the maximum amount of energy. With the increasing adoption of solar energy and the need for more efficient and cost-effective solar energy systems, the development of a solar angle optimizer has become more important than ever.

Energy capturing from the sun depends on several crucial characteristics. The most crucial aspects are:

- the position of a photovoltaic panel in relation to the incident solar radiation.
- a certain surface's cumulative solar radiation over time (days, months, and years).
- impacts on the atmosphere, including as absorption and dispersion.
- the time of the day and the season.

The angle of the sun with respect to the solar panel must be optimized in order to be able to use solar energy as efficiently as feasible. A motorized technology is employed to maintain the solar panels' ideal angle to the sun to increase their energy capturing efficiency.

2 System Description

2.1 The Rig

The rig consists of a mast with two-axis motor. Rated voltage of each motor is 24 VDC and rated current is 5 Amps. Internal gear ratio of this motor is 575:1. The worm gears have a gear ratio of 73:1. So the actual gear ratio is 83950. This high gear ratio prevents the mounting frame from moving when the motor is stationary.

Additionally, the motors have Hall Effect sensors that produce two pulses for every rotation. These sensors are extremely polarity sensitive, therefore using the incorrect polarity while wiring, might result in damage to the sensors. These sensors are utilized to know the motor drive's exact position at all times.

A H-bridge motor drive is used to control the motor through PLC. By switching polarity, this H-bridge enables the motor to operate in both the forward and reverse directions. The H-bridge is constructed in such a way that it can handle a sufficient amount of current during switching and can transition quickly. The Dual Axis Rig is shown in Figure 2.

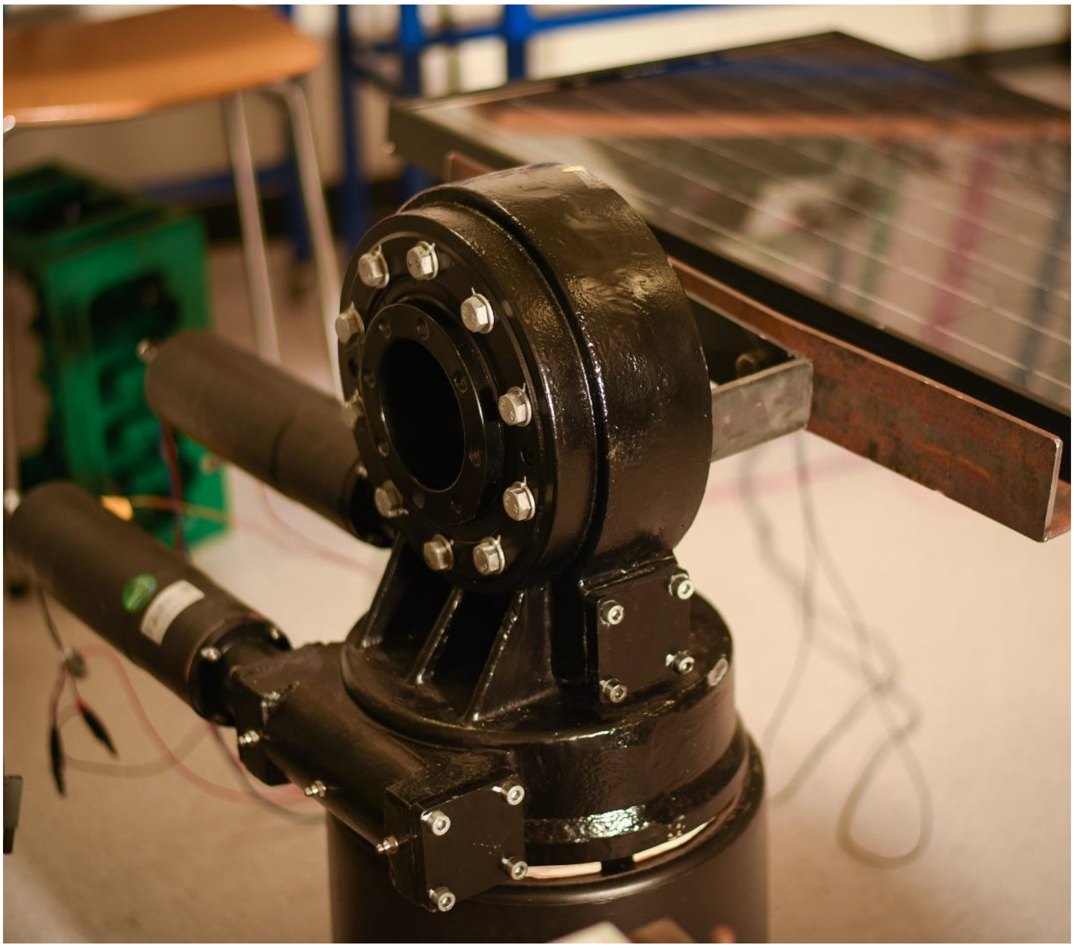


Figure 2: Dual Axis Rig

The setup is wired with several cables. The cables will rip apart if the rig rotates beyond a specific limit. Additionally, it has the potential to harm several components. To prevent this to happen, two induction sensors are mounted on azimuthal direction and two on the tilt direction. These induction sensors are also used while initializing the panel's position.

An anemometer with a measurement range of 0.3 to 60 m/s is used to measure the wind speed. The anemometer's output signal is DC voltage and is linear to the wind with a sensitivity of 0.164 Vs/m. The anemometer requires 24 VDC which is supplied from the PLC.

A pyranometer is incorporated with the system for comparing the power acquired by the panels and actual irradiation of the sun. The pyranometer has a sensitivity of 49.5 µV/W/m^2. It gives output as DC voltage and requires no external voltage supply.

2.2 The Programmable Logic Controller (PLC)

Wago PFC200 PLC is used for this project. The PFC200 is compact and convenient for WAGO I/O System. It is compatible with all the digital, analog, and specialty modules of 750/7503 series. PFC200 supports SD card as well, which is used to log the result data. The I/O modules used for this project are as below:

750-404/000-003: This is a frequency module which counts the 12-24 V pulse period at the CLOCK input. This module is used to count the pulses generated from the motor. The output signal from Hall Effect sensor is connected at the CLOCK input of this module. The power for the Hall Effect sensor is also provided from this module. There are two frequency modules for two motors.

750-455: This is a 4-channel analog input which can process standard 4 to 20 mA signals. The 4 induction sensors are connected to this module.

750-504: This digital output module has four channels. The device sends 24 VDC control signals through this module to the linked actuators, in this instance the H-Bridge motor drive. As the output current is only 0.5 A from this module, an external power supply is needed for the H-Bridge and the output signals are utilized just to trigger the relays of H-Bridge.

750-640: This is a real-time clock module designed to provide accurate timekeeping functionality for applications that require time synchronization. It can also be configured to synchronize with an external time source, such as a GPS receiver, to ensure precise timekeeping. Sun's position is calculated using this module.

750-468: This is also a 4-channel analog input module. But it differs from the 750-455 module as it processes standard 0 to 10 V signals. The anemometer and pyranometer is connected to this module.

3 Methodology

3.1 Perturb and Observe Method:

The Perturb and Observe method is a popular technique used in maximum power point tracking algorithms for photovoltaic systems. Its purpose is to optimize the power output of a PV system by continuously adjusting the operating point of the PV panel to track the maximum power point.

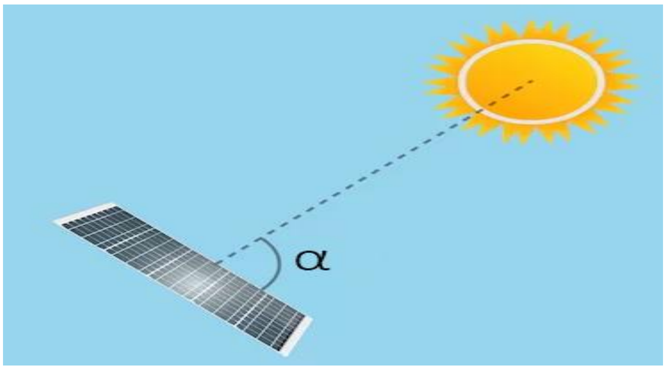


Figure 3: Solar angle on PV panel

Power output from a PV panel highly depends on the angle between the sunlight and the panel, among other factors.

$P_{out} = P_{max} * \cos \alpha$ …………… (1)

where, P_{out} = Output power of the PV panel

P_{max} = Maximum/ Peak power of the PV panel

α = Angle between the sunlight and the PV panel

To reach the maximum power point, the controller starts by initializing the operating point of the PV panel. In this project, the initial point is set by calculating the sun's position. Then the operating point perturbs (changes) slightly and measure the power. After perturbation, new power output is compared with the previous power output.

If the power increases, perturbing in the same direction is continued assuming it is still approaching the maximum power point.

If the power output decreases instead of increasing, the direction of the perturbation is changed in the same manner. This process is repeated in a continuous loop, gradually adjusting the operation point of the PV panel based on the power comparison.

3.2 Program

All the codes are written in e!cockpit software. The e!cockpit offers a user-friendly interface and a number of tools to help speed up the programming process and ease the development and management of automation projects. It has built-in debugging tools and simulation capabilities, and it supports a number of programming languages, including ladder logic, Structured Text (ST), and function block diagram.

In previous work, a ladder logic was used for the motor control while the other codes were written in ST but in this thesis, all the codes are written in ST which made the program convenient.

There are supposed to be 5 main programs: Initializing, Locating the Sun and adjusting the panel accordingly, Optimizing, Tracking the sun and a program for Storm Mode.

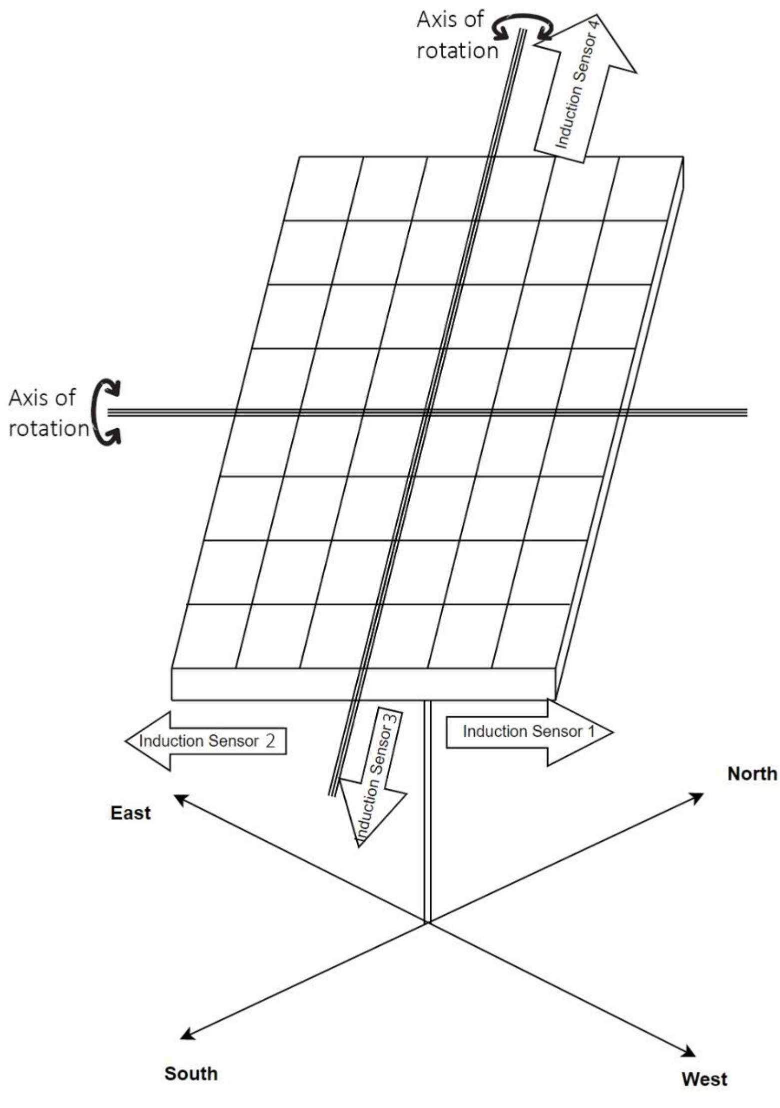


Figure 4: Induction sensor’s tentative positions

The PLC cycles through the code continuously. The system starts with the 'Initializing' mode. At the starting, panel's position is unknown. So, to initialize, the azimuth and the tilt positions are considered at predefined angles in accordance with the induction sensors. Induction sensor's tentative positions are shown in the Figure 4.

And then it starts calculating the sun's location and position the panel perpendicular to the sun. Then it starts checking for optimal position. It starts by varying the azimuth angle first. When the azimuth angle reaches optimal position, tilt angle optimization comes into action.

When both the angles are in optimal position, the panel stays there for several minutes. Then again the system checks for another optimal position. If the optimal position changes, the panel is oriented accordingly, which is a continuous process.

At any time and in any mode, if the wind speed is 20 m/s or more, Storm Mode enables. And the panel goes to 0-degree tilt position. The azimuth angle remains unchanged. If the wind speed is below the limit for at least 10 minutes, the panel goes back to the position where it was before the storm.

While in tracking mode, if the azimuth angle reaches to a given limit (330° in this regard) or the sun is under the horizon, the panel will come back to its initial position. Limiting the rotation to 330° prevents the wires to be torn off.

The irradiation was calculated within PLC using the equation 2.

$$\text{Irradiation} = v/s \quad \ldots\ldots\ldots\ldots \quad (2)$$

Where, v= voltage reading from the pyranometer.
S= 49.5 (Sensitivity of the pyranometer)

3.3 Algorithm

The algorithm is constructed in a way that reduces complexity and increases program efficiency. To have a clearer picture how the whole system works, the algorithm is presented in two sections. One is the overall structure & the other one is the detailed structure of every stage.

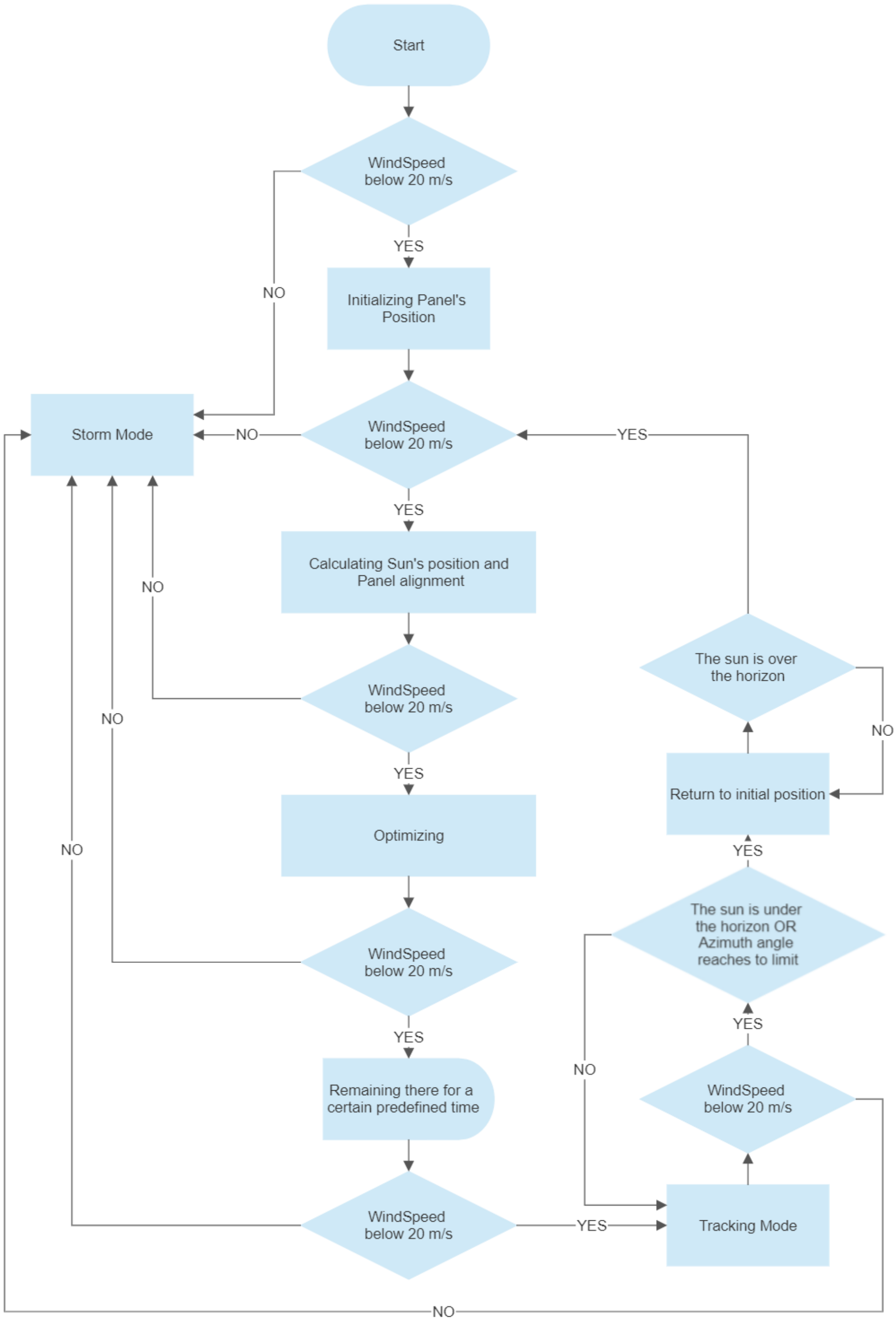


Figure 5: Overall algorithm flowchart

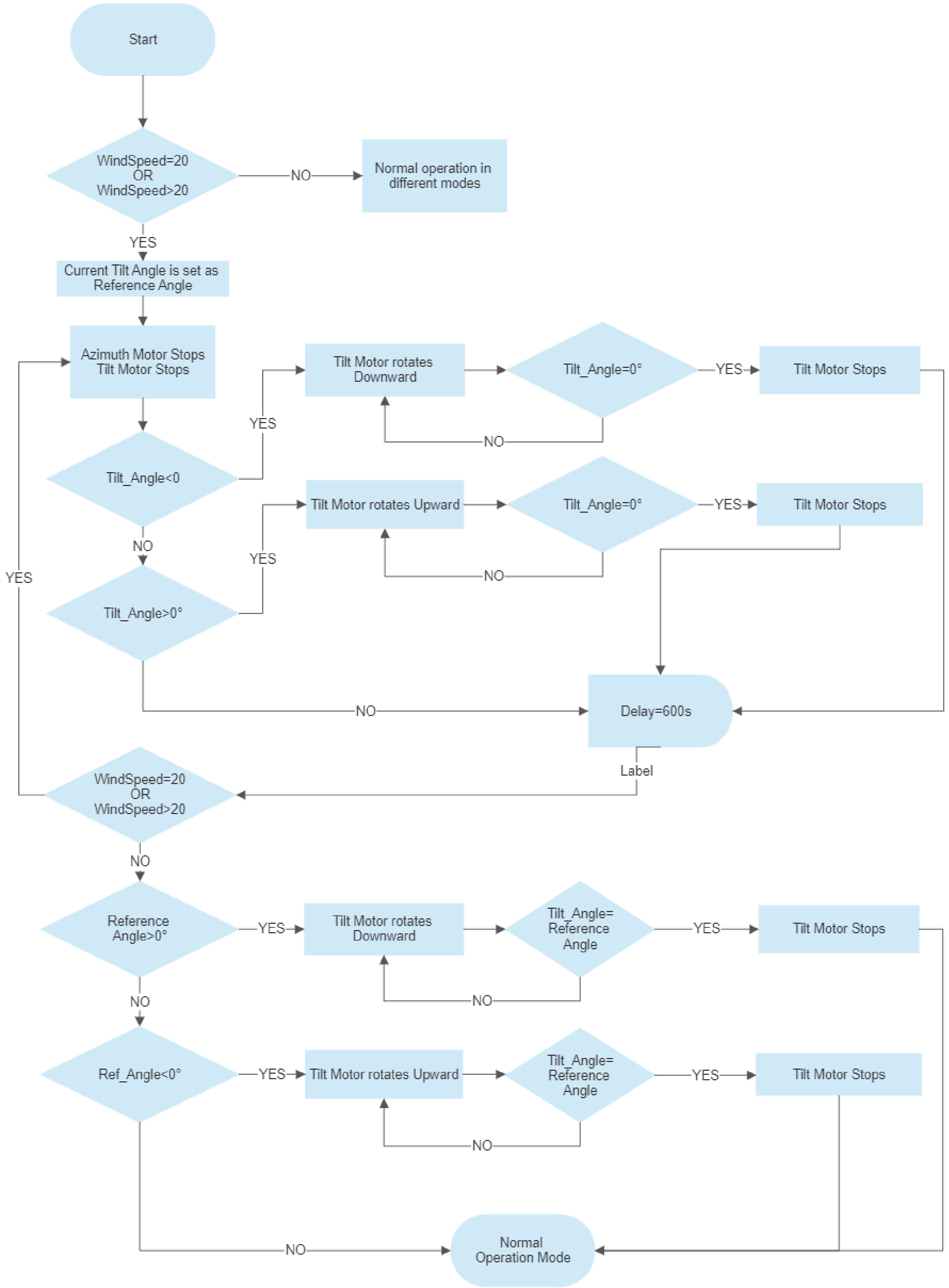


Figure 6: Algorithm flowchart of 'Storm mode'

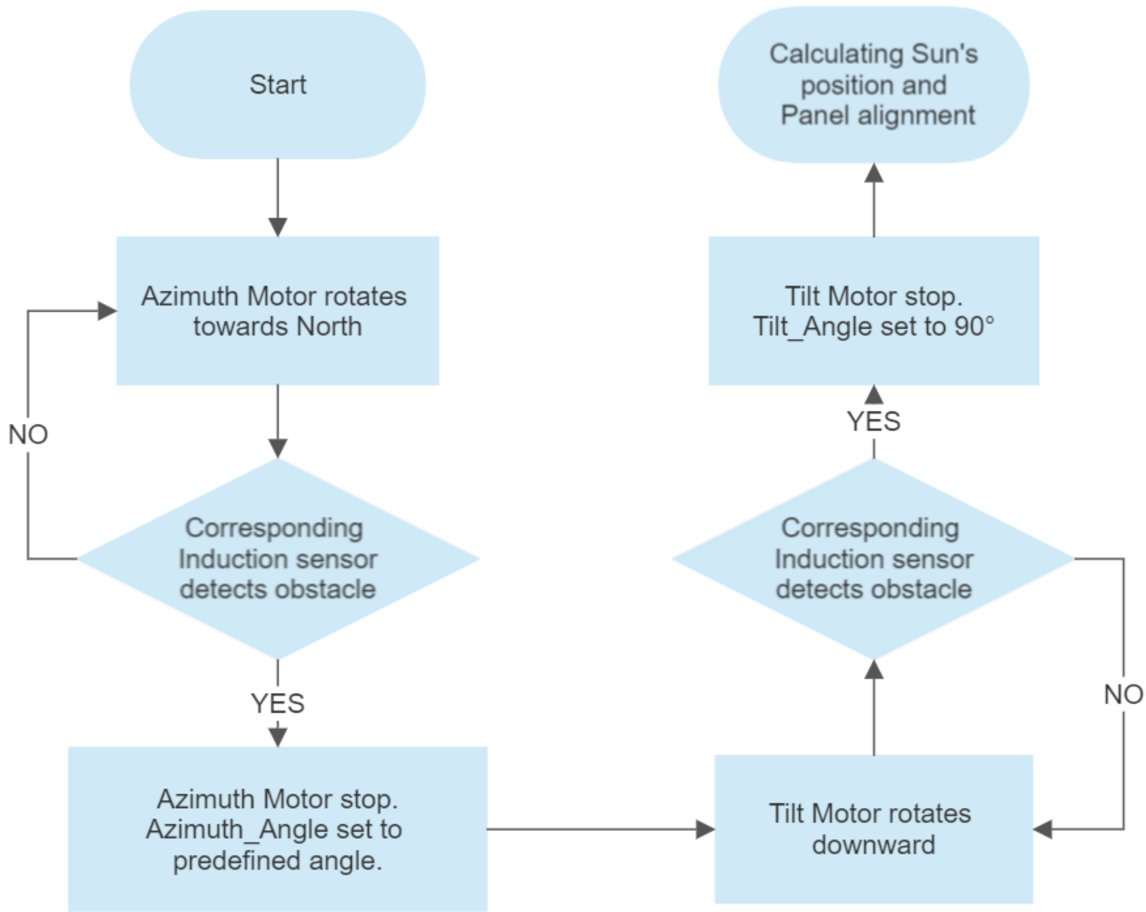


Figure 7: Algorithm flowchart of 'Initialization'

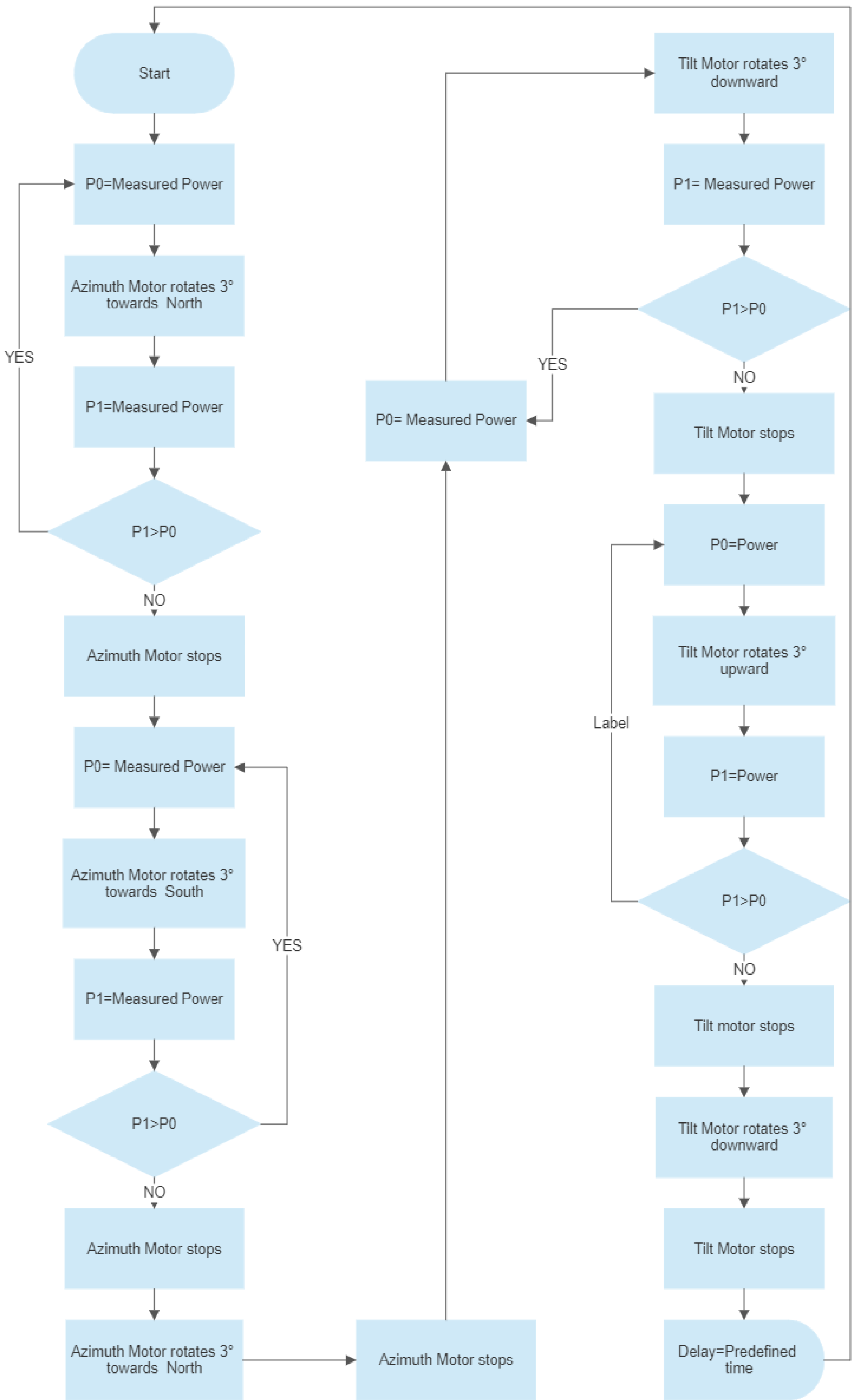


Figure 8: Algorithm flowchart of 'Optimization and Tracking'

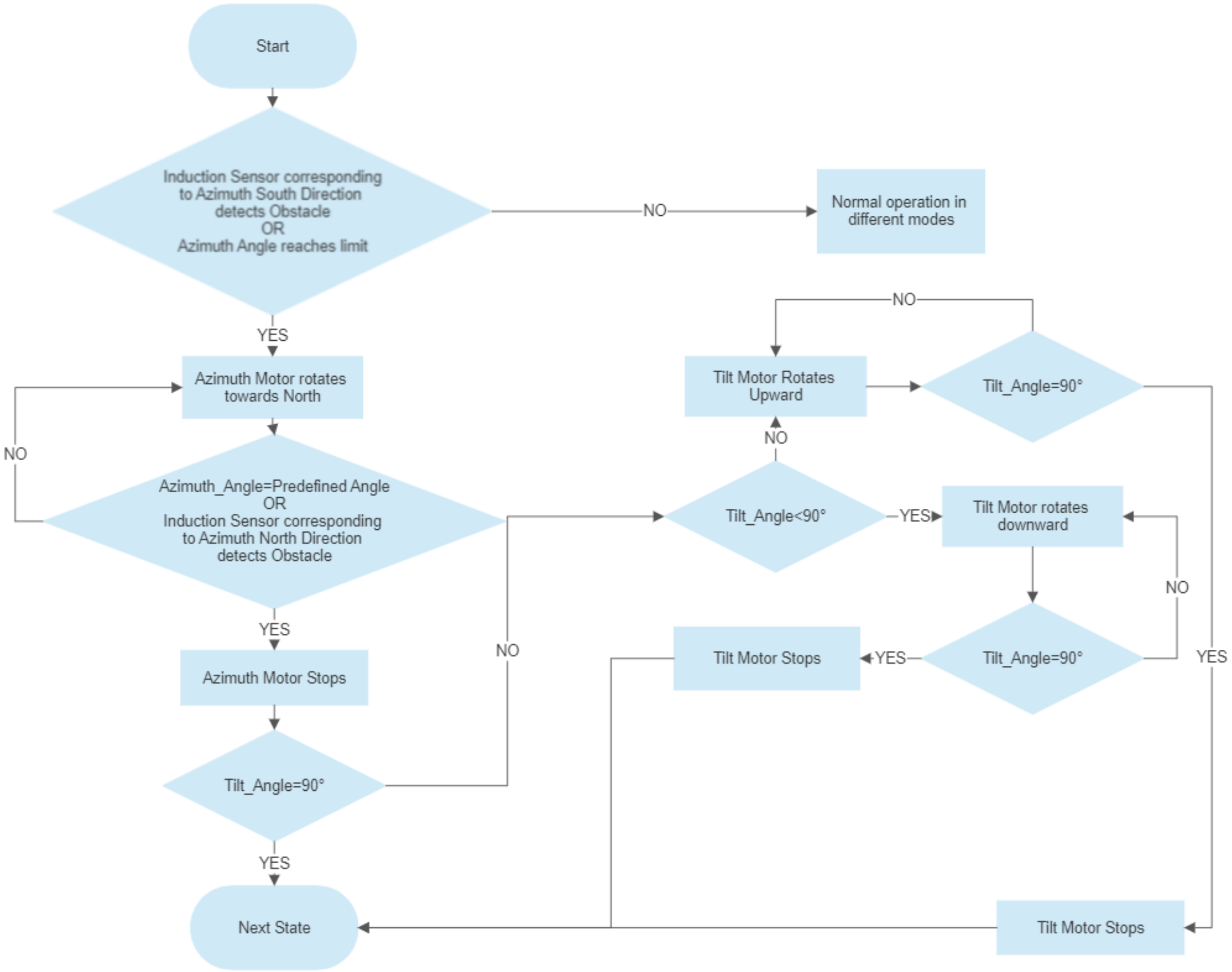


Figure 9: Algorithm flowchart of ‘Returning’

4 Practical work

4.1 Printed Circuit Board (PCB) of H-Bridge motor drive

The PCB was designed in "Altium Designer" software. 'HF140FF' miniature relay with a switching capability of 10 A was used. Having 2 channels in each module, total 4 modules were used. A dual layer PCB was designed and printed.

Circuit diagram of H-Bridge for a single motor is shown in the Figure 10 as the circuits are identical for both motors.

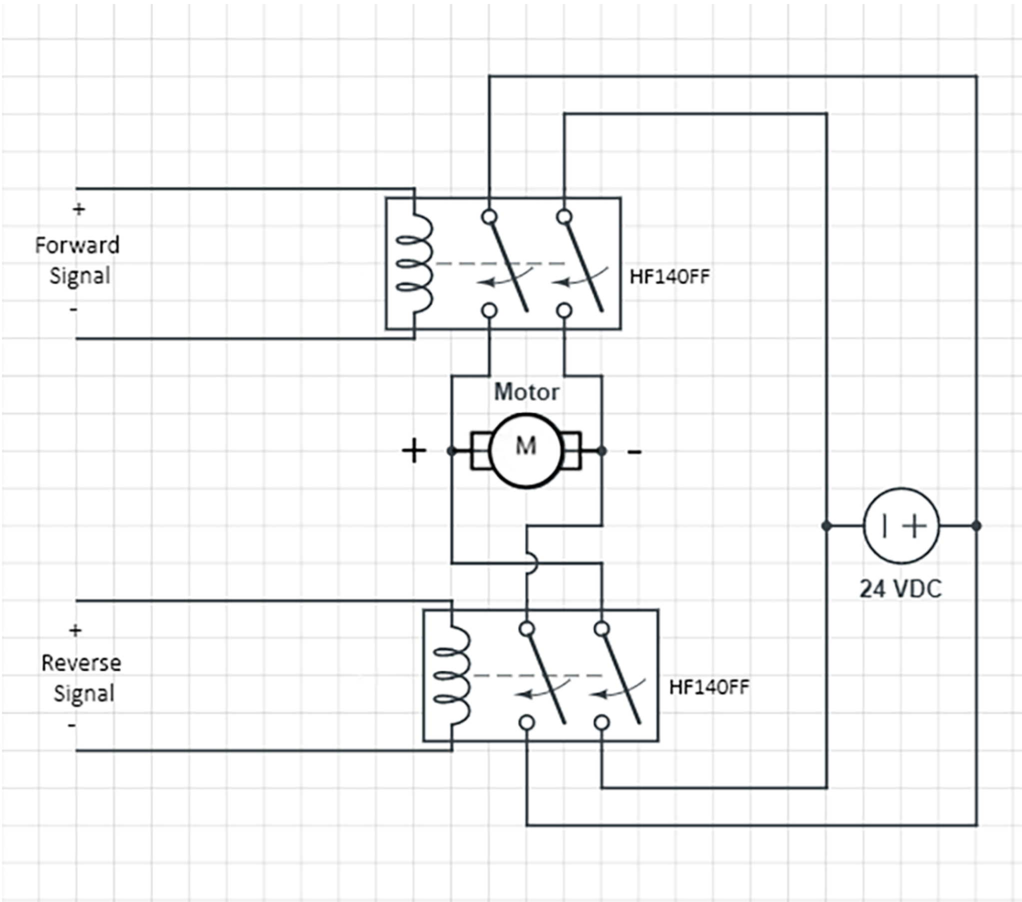


Figure 10: Circuit Diagram of H-Bridge Motor drive

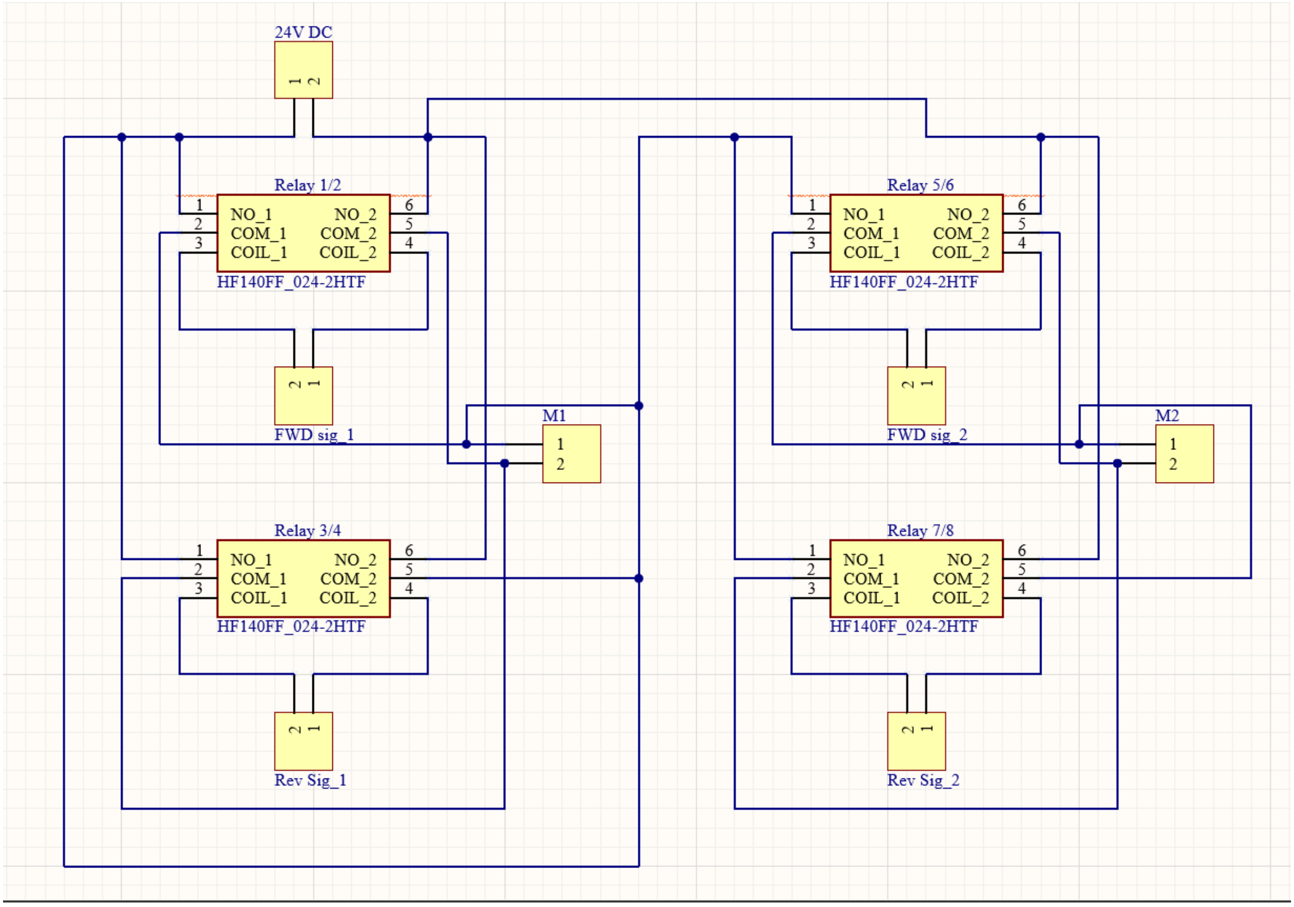


Figure 11: Schematic Diagram of the H-Bridge

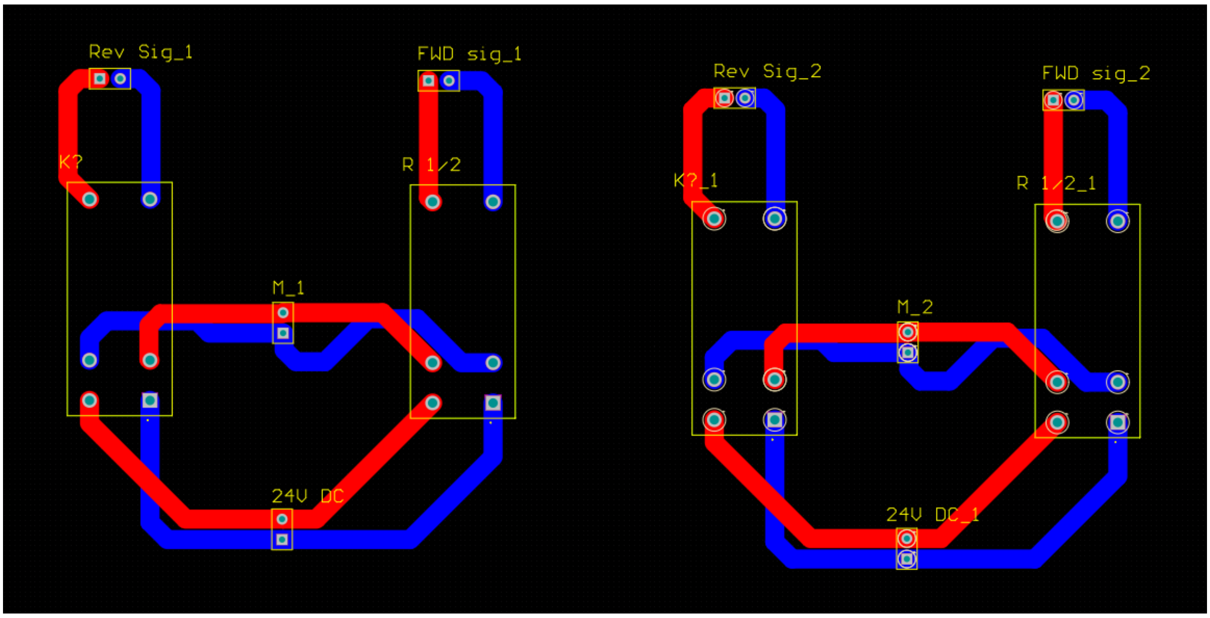


Figure 12: PCB Layout of the H-Bridge

4.2 Printed Circuit Board (PCB) for power measurement

In the previous work, to measure the power from the solar cell panels LEM elements were used, to measure voltage and current. The board was designed to measure the voltage, current, and power output of a DC power source. In the current study, a test was performed to check if the power measuring PCB was performing as expected.

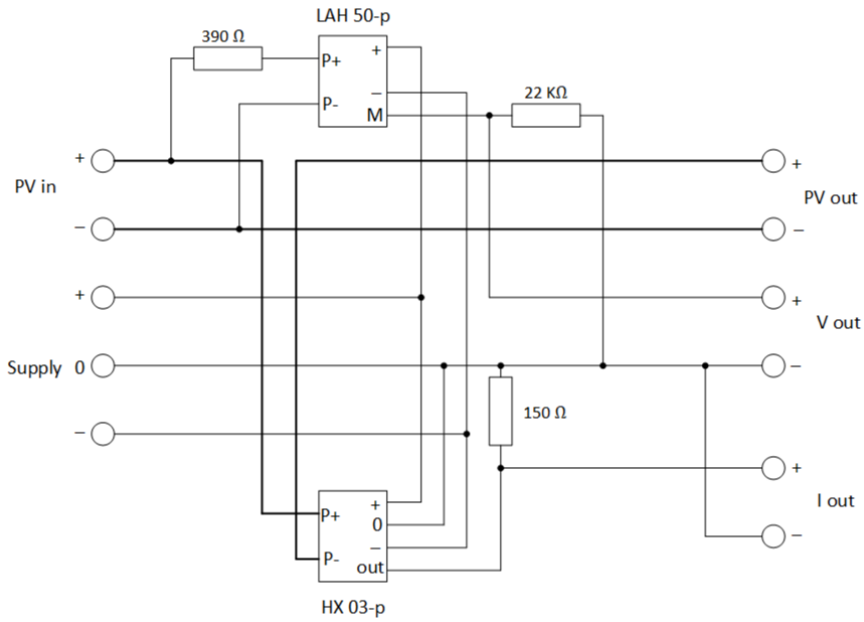


Figure 13: Circuit diagram of power measuring board

Test:

To conduct this test, a DC power supply capable of providing up to 42 V and 20 A was used as PV IN. Two 24 VDC motors were used as load (PV Out).

The voltage measuring component LAH 50-p was tested using a variable voltage supply from 10 to 42 VDC. But the current measuring component HX 03-p was measured at a fixed voltage of 24 VDC as that was the rated voltage for the motors, used as load. The measuring elements were supplied proper voltages (+15, 0, -15) from trainer board.

The following results were obtained from the lab test:

Test result of LAH 50-p:

PV IN (Volt)	LAH 50 reading (Volt)
10	-0.73
15	-0.59
20	-0.45
25	-0.31
30	-0.176
40	0.104
42 (Max)	0.156

Table 1: Test results of LAH 50-p

The voltage was measured across the 22 K ohm resistor connected with “M” terminal of LAH50-p.

Test result of HX03-p:

	Multimeter Reading (Amp)	HX 03 Reading (Volt)
1 motor running	1.2	1.4
2 motor running	2.63	3.54

Table 2: Test result of HX03-p

The voltage was measured across the 150-ohm resistor connected with the “output” terminal of HX03-p.

The results of the lab test indicate that the power measuring PCB board can measure the voltage & current. But unfortunately, the voltage readings are not accurate for low input voltages.

And regarding current measurement, the reading seems quite accurate. But the current to voltage conversion ratio is not appropriate for the PLC. Because when all the 8 panels will be mounted, the current will reach up to 24 A and then HX 03 voltage reading will be around 36 V. But the PLC can read up to 10 V.

Also, according to previous project report, the measuring board can’t sustain the whole PV panels current. Rather it was designed to measure the power of a single PV panel.

As the time was limited, no new power measuring board was built. Rather some prebuilt devices were used for measuring voltage and current. The PLC can read only voltage within the range 0-10 V. So, the voltage reading was stepped down with a ratio of 100:1 and the current was converted to voltage with a ratio of 1 A:0.4 V.

Rest of the tests were done with PLC and all the connected components and sensors. The components and sensors were connected as shown in Figure 14.

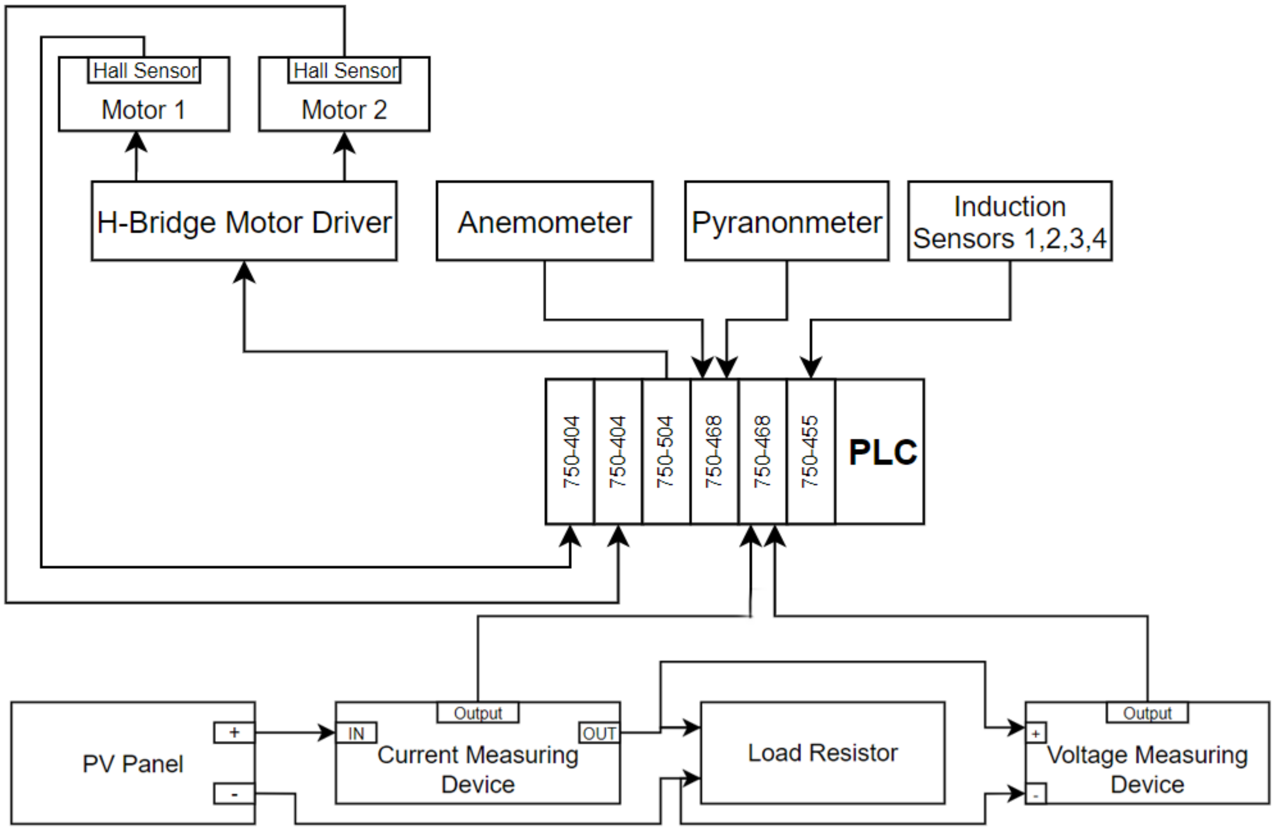


Figure 14: Connection Diagram of the whole system

4.3 Induction sensors/Obstacle avoiding test

The aim of this test was to check if the Induction sensors were working perfectly and preventing the rig from hitting any obstacle and to check if it was moveable on the opposite direction while having obstacle in other direction.

The test was conducted by running the motors manually and a metal object was placed in front of the sensor to represent obstacle. The Human Machine Interface (HMI) in figure 15 was created within e!cockpit for this test.

Figure 15: HMI for Induction sensors/Obstacle avoiding test

While testing in the HMI [Figure 15], both the motor 1 reverse (M1 REV) and forward (M1 FWD) switches were on. It was indicated by the green light beside 'M1 FWD' that the motor was running in forward direction and by the red light beside 'M1 REV', the motor was not running in reverse. It was also indicated by the green light beside 'Obstacle in Motor1 reverse direction' that the obstacle was detected in reverse direction for which the motor was not running in reverse direction even though the switch was on.

Other three sensors were tested in the same manner. Result data was logged into 'Data logger' program at an interval of 2 seconds. Retrieved data from the program was plotted through Matlab.

Results:

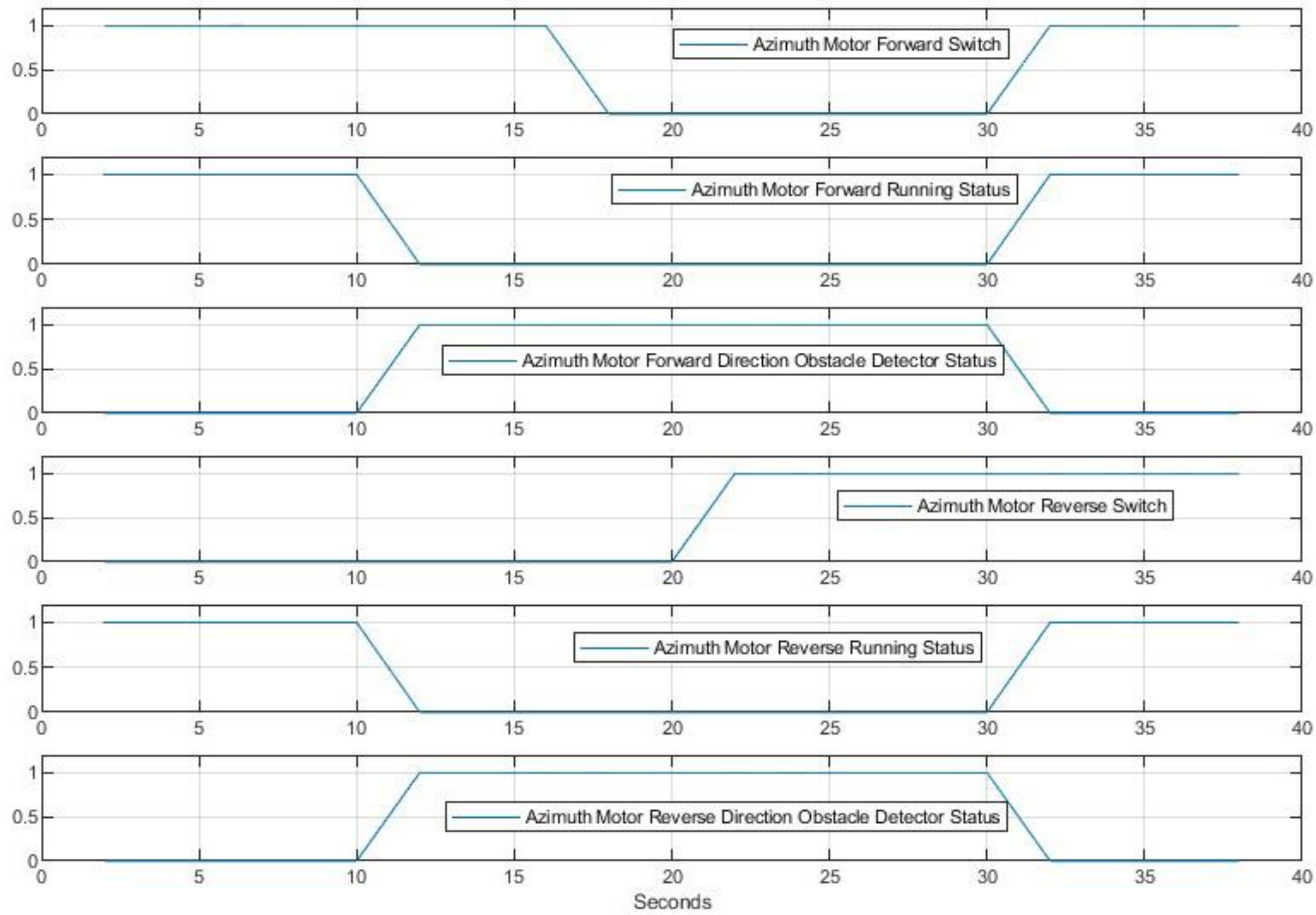


Figure 16: Induction sensors/Obstacle avoiding test result for Azimuth Motor

The forward switch was 'ON' from 0-16 second and the motor was rotating in forward direction. At 12th second, obstacle was detected in forward direction and the motor stopped immediately. When the reverse switch was turned ON at 22nd second, the reverse obstacle status was 'LOW' and the motor started reversing as the forward obstacle status was 'HIGH'. Again, at 32nd second Reverse obstacle status was 'HIGH' which caused the motor to be stopped immediately, even though the reverse switch was turned ON.

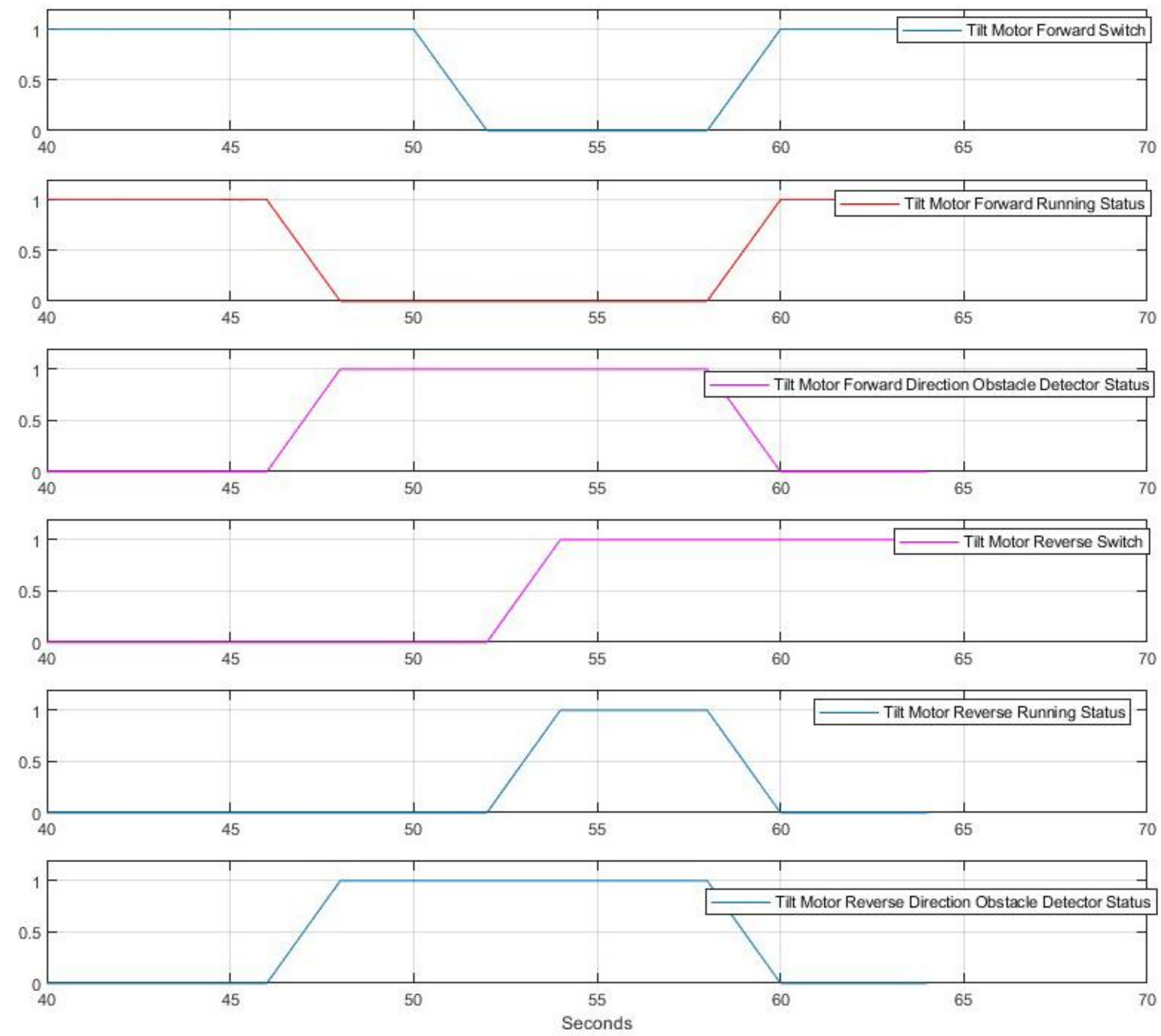


Figure 17: Induction sensors/Obstacle avoiding test result for Tilt Motor

Similar result was found for Tilt Motor, which led to the conclusion that the sensors can stop the motors if any obstacle is found in either direction while allowing for movement in the other direction.

4.4 Initialization & Returning Test

Two tests were performed in this segment. The initialization conditions were same in both tests. But the returning was tested under two different conditions; one was by limiting the azimuth angle and other one was using Induction Sensor.

In the initialization process, azimuth motor (Motor1) started reversing until Induction sensor 1 found an obstacle. Following that, azimuth angle was set as 15°. After setting the azimuth angle, the tilt motor (Motor 2) began to reverse until the induction sensor 3 detected an obstacle, at that point the tilt angle was set as 90°.

For the purposes of this experiment, the azimuth angle limit was set at 65°, and it was checked if the panel returned to its starting location if the azimuth angle reaches 65°. In practice, this angle will be set to a much higher limit. The motors were driven manually during the test to increase azimuth and tilt angle.

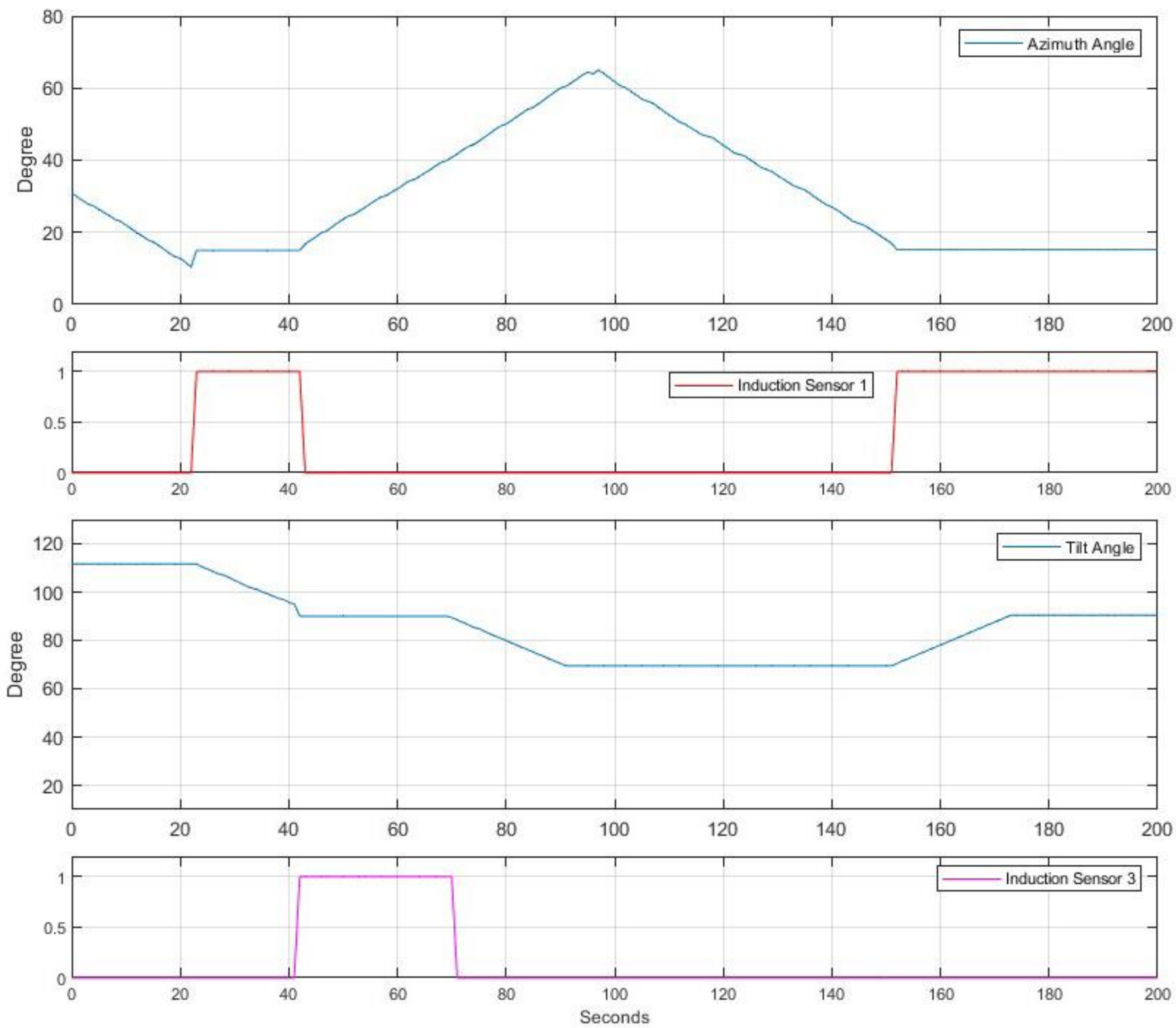


Figure 18: 'Initialization & Returning by limiting azimuth degree' test result

In figure 18, Azimuth motor was reversing at the beginning. At around 23rd second Induction sensor 1 detected obstacle. The motor stopped there, and azimuth angle was set to 15°. Then Tilt motor started reversing and at around 42nd second Induction sensor 3 detected obstacle. The motor stopped immediately, and tilt angle was set to 90°. Then the angles were increased by running the motors manually.

At around 97th second azimuth angle reached to 65°, thus returning program came to action and azimuth angle started decreasing. When azimuth angle became 15° at around 152nd second, the tilt angle started increasing as the panel had to go at 90° tilt position. It reached at 90° at around 174th second.

For this experiment, there no limit was set for the azimuth angle as the Induction sensor was to be tested. The test result is presented focusing only on azimuth angle.

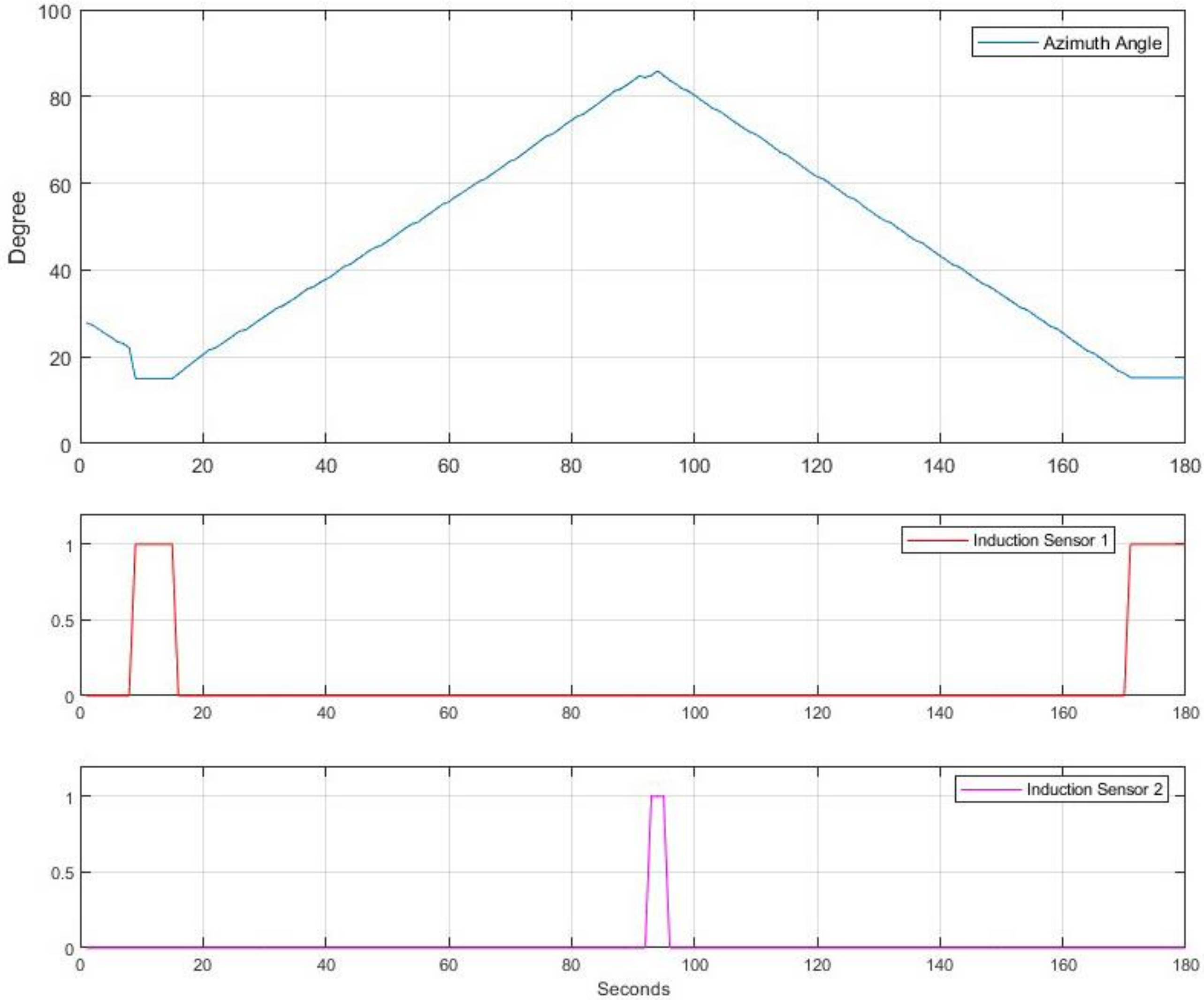


Figure 19: 'Initialization & Returning by Induction Sensor' Test result

In case of 2nd experiment, in figure 19, the panel's position was initialized similarly like previous experiment. The azimuth angle then began to rise. Induction sensor 2 identified an obstacle at 94th second, when the azimuth angle was about 86°. Then azimuth angle began to decrease until it returned to its starting point.

In the test results, the azimuth angle in the event of a return was 15.16°–15.19° and the tilt angle was 90.89°. The outcome was therefore acceptable, which indicated that the algorithm also functioned as expected.

4.5 Optimization and Tracking test

For this test a strong light source was used with a crane. So that it could be moved from left to right & up down direction.

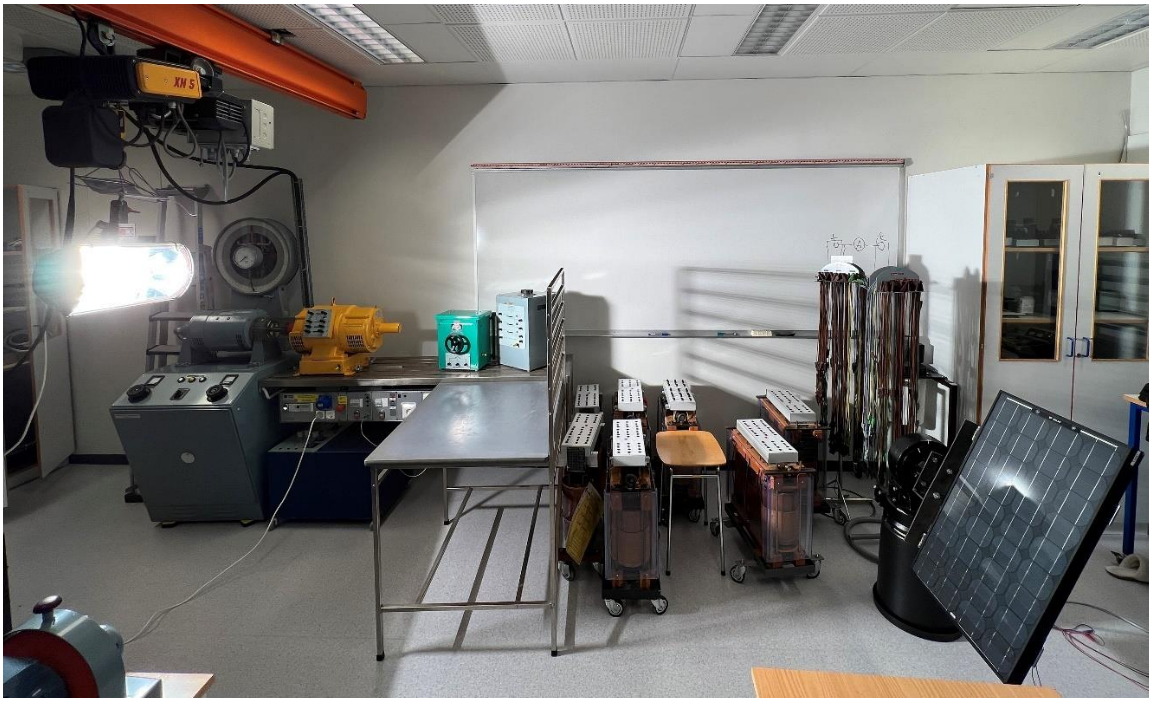


Figure 20: Experiment setup for Optimization & Hovering test

A 630 Ω variable resistor was used as load for this experiment. The resistor was set to 451Ω. As at this setting the panel was providing maximum power which was 2-2.4 watt.

Two separate devices were used to measure the voltage and current. To make the voltage & current reading compatible with PLC, the voltage was stepped down with a ratio of 100:1 and current was converted to voltage with a ratio of 1A: 0.4V. Because of these multiple devices and conversions, the power reading was very unstable. The power was calculated within PLC program using equation 3.

$$P=(v * 100) * (i * 25) \quad \text{………………………… (3)}$$

where, P=Power

v= Voltage reading

i= Current reading

Circuit shown in Figure 21 is used to measure the power of the PV panel.

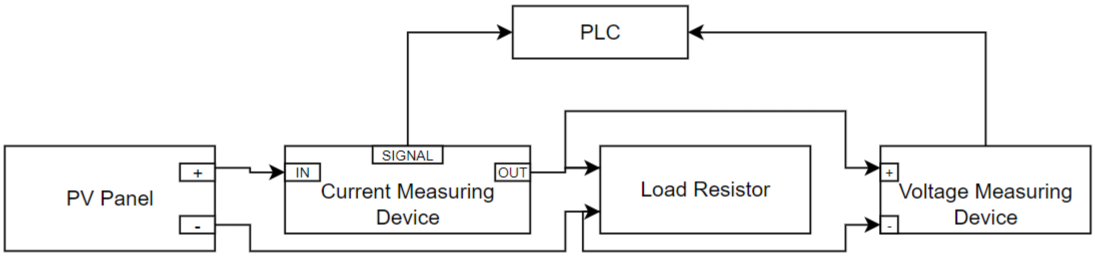


Figure 21: Circuit diagram of Power measuring arrangement

Though the interval between optimizing and tracking mode was few minutes in actual algorithm, for the sake of this test, the interval was set to 1 minute. Which means, it would check for new optimal position within short range in every minute after optimization. And while testing, the position of the light source was changed during this 1-minute interval.

As the Sun's position calculation program was not implemented, so the optimization started from a random position while facing the panel towards the light source.

Result data was logged into 'Data logger' program at an interval of 2 second. Retrieved data from the program is plotted through Matlab.

The HMI in figure 22 was created within E!Cockpit to monitor important data during the test.

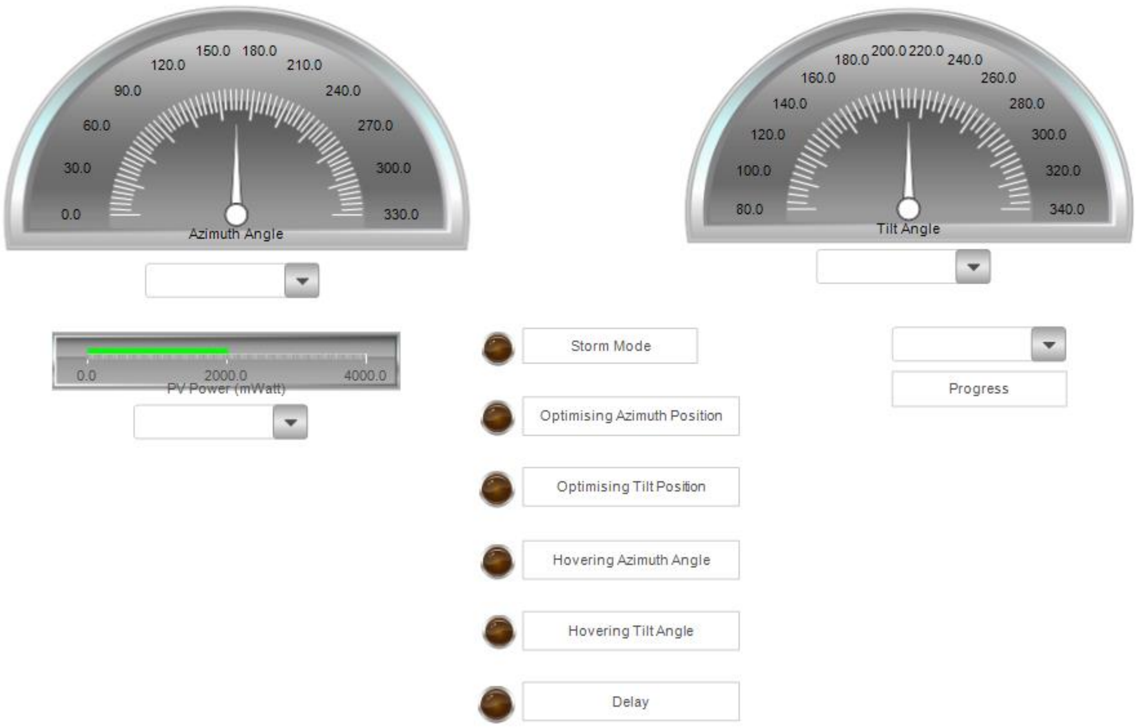


Figure 22: HMI for monitoring data during Optimization & Hovering

Results:

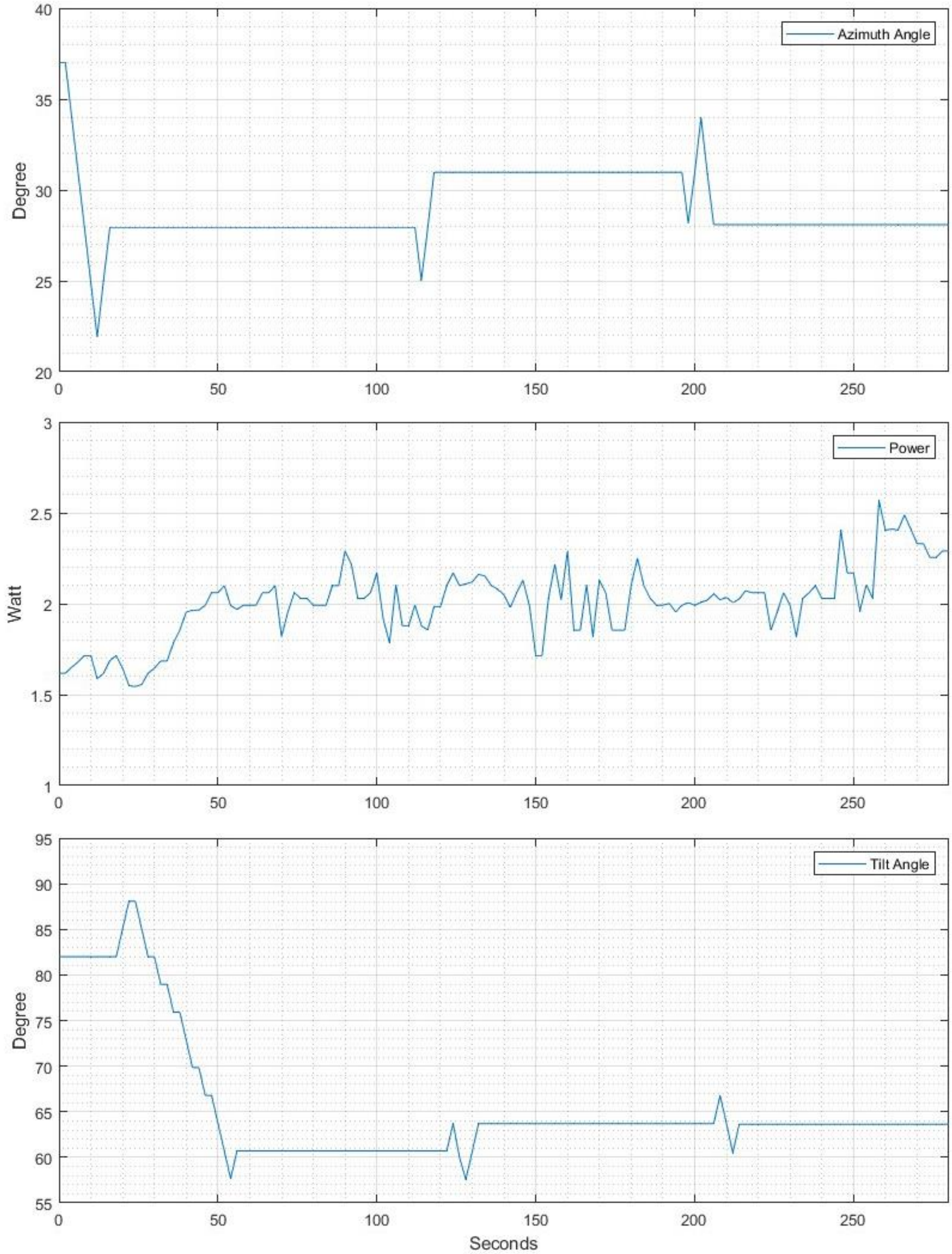


Figure 23: 'Optimization & Tracking' test result

From the result plot, it was observed that the panel was optimizing up to around 54th second. After that it was idle for a minute. Then it entered tracking mode and checked for optimal position within short range. Two tracking cycle is represented in the result. Some major fluctuation is observed in the power curve within 54^{th} to 114^{th} second & 136^{th} to 196^{th} second. This is because, the light source was blocked sometimes while changing its position.

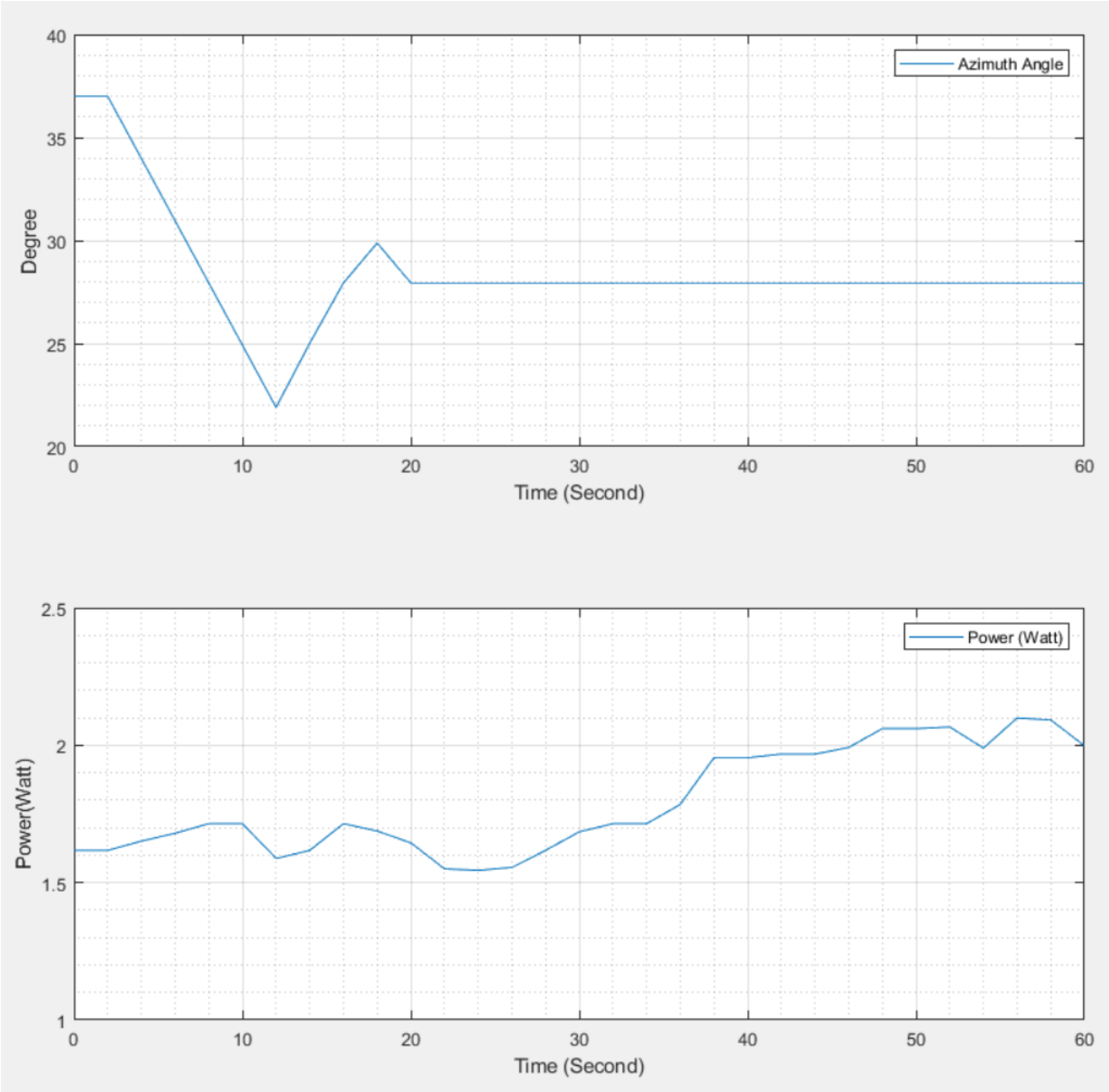


Figure 24: Closer view of Azimuth angle while optimizing

With a closer look [Figure 24], the azimuth motor was reversing till 12th second as the power was increasing in this direction. But the power started reducing after 10th second. So, the panel stopped there and started moving to opposite direction. It moved up to 18 second mark as the power started reducing after 16 second mark. Which means the maximum power was 1.7 Watt at 16 second mark. And during 16th second the azimuth angle was around 28°. So, the panel went back to 28° Azimuth position. Then the tilt angle optimization started.

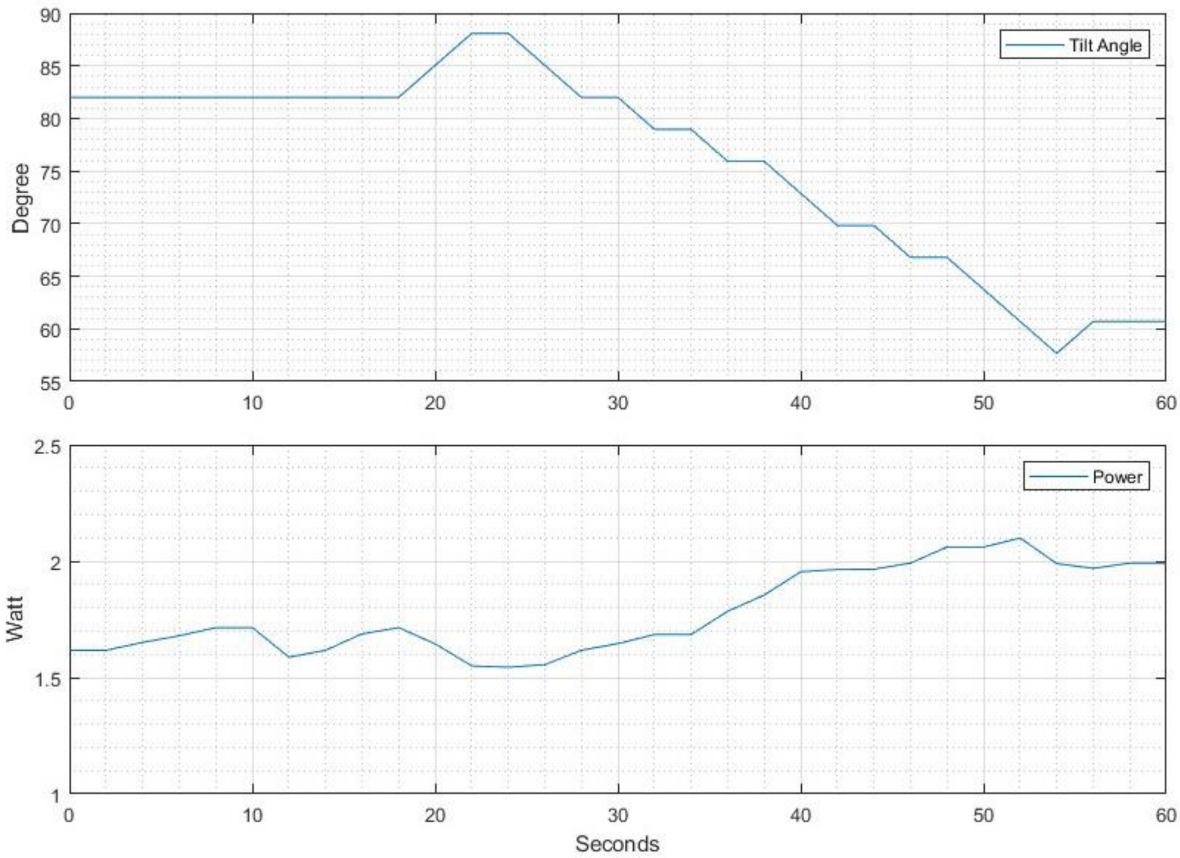


Figure 25: Closer view of Tilt angle while optimizing

In Figure 25, the tilt angle started optimizing from 18th second. The tilt motor reversed till 22 second mark, but the power was reducing at that direction, so it started moving to opposite direction and the power was uprising up to 52 second mark. At 54 second mark the power reduced, so the motor stopped, and the panel went back to around 119° tilt angle position. As that was the position at 52 second mark where the power was maximum with the value close to 2.1 Watt. Then it remained idle for one minute. Within this one minute the light source was moved towards right and lowered a bit. After one minute first tracking cycle starts.

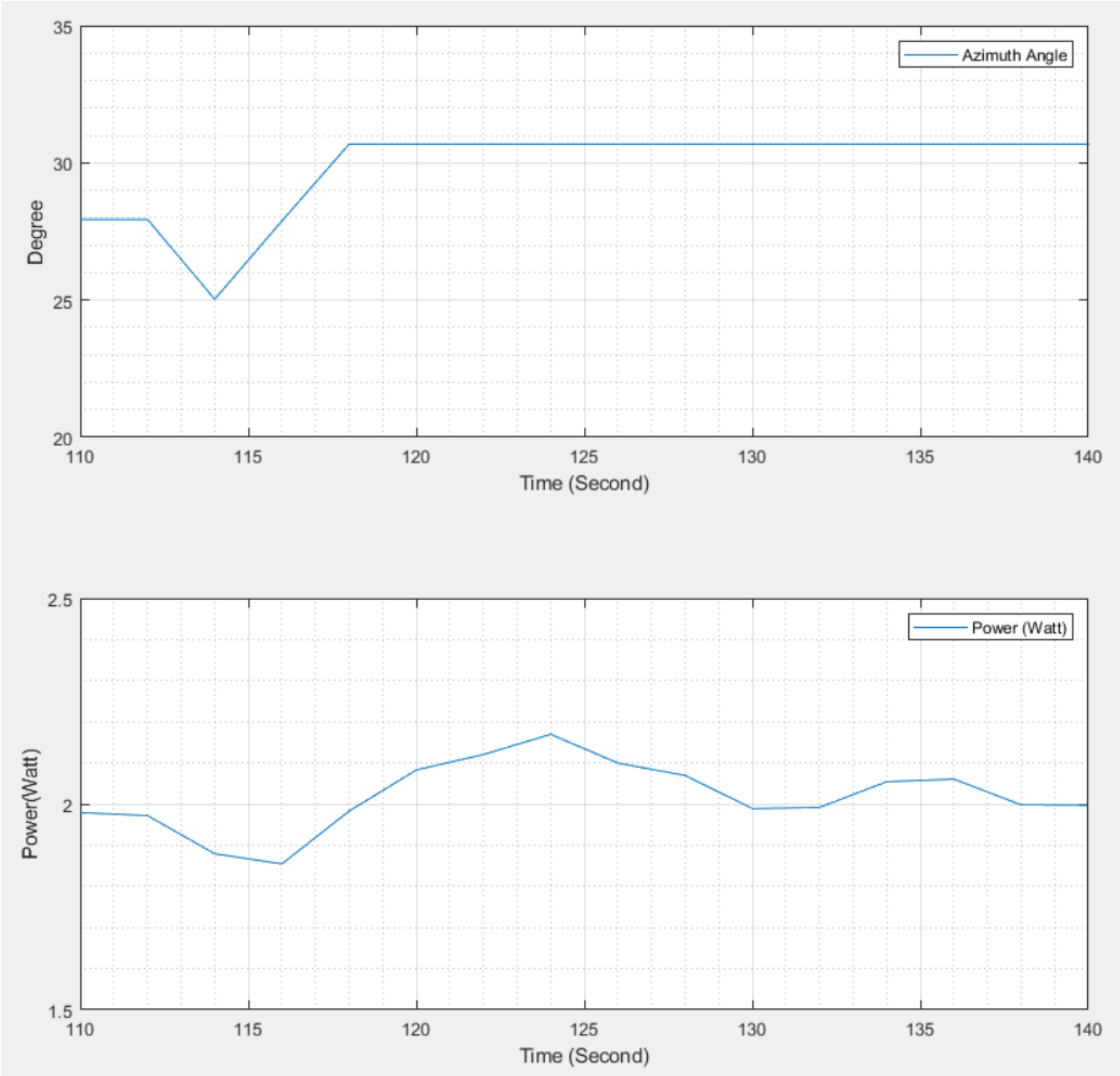


Figure 26: Closer view of Azimuth angle while tracking (Cycle-1)

In Figure 26, tracking in azimuth angle began to act at 112th second. The motor reversed 3° and then forwarded 6°. The power at 31° azimuth position at 118 second mark was the maximum, so the panel remained there, and tracking in tilt position came into action.

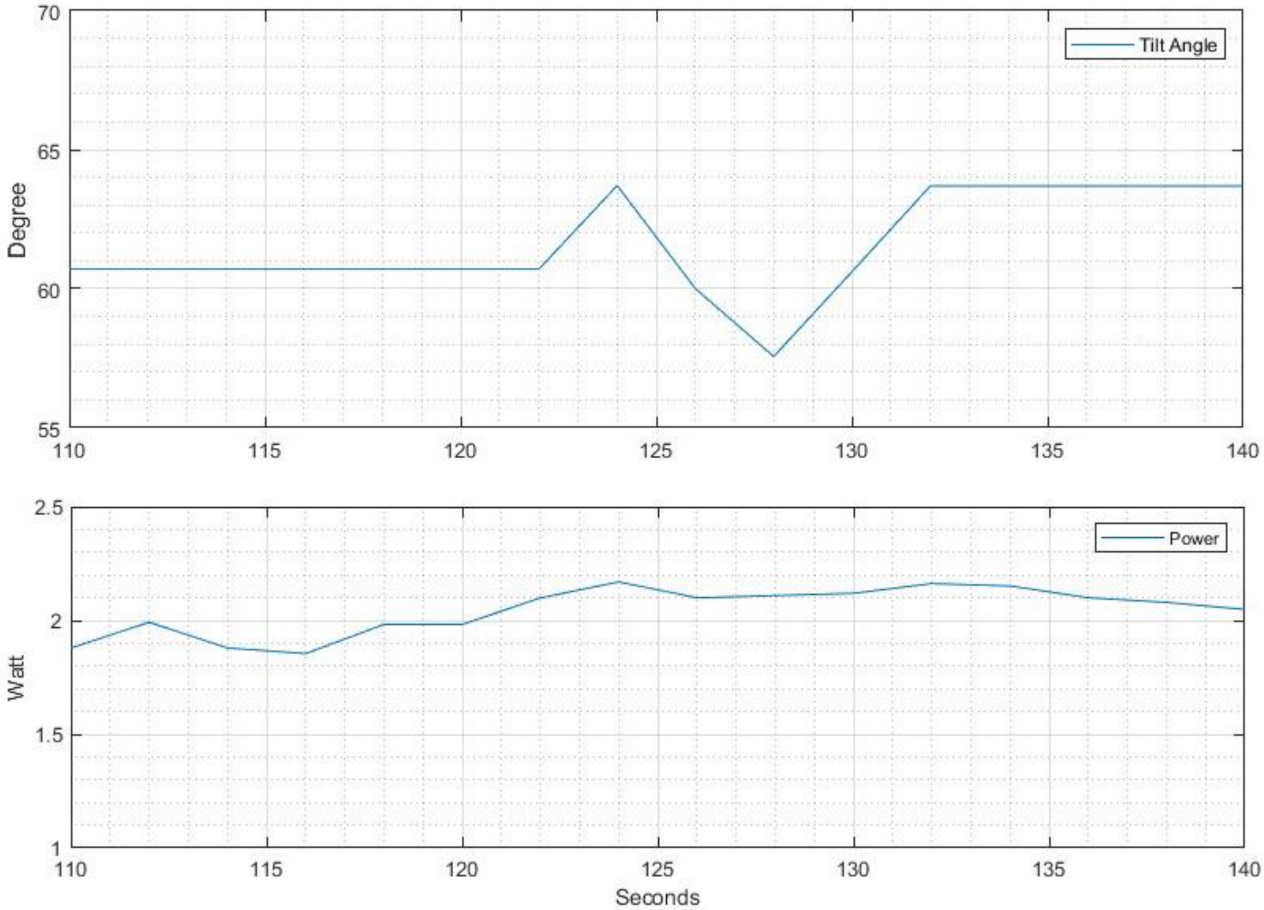


Figure 27: Closer view of Tilt angle while tracking (Cycle-1)

After setting the azimuth angle, tilt angle started increasing from 122^{nd} second [Figure 27] while the panel was at 61° tilt position. It reversed 3° then forwarded 6°. The power was maximum at 124^{th} second when tilt angle was around 63.7°. So, the panel reversed back to 63.7° tilt position and settled there for 1 minute. The power at that point was about 2.1 Watt.

The light source's position was changed once again. This time it was moved left, keeping the height unchanged one more cycle was experimented.

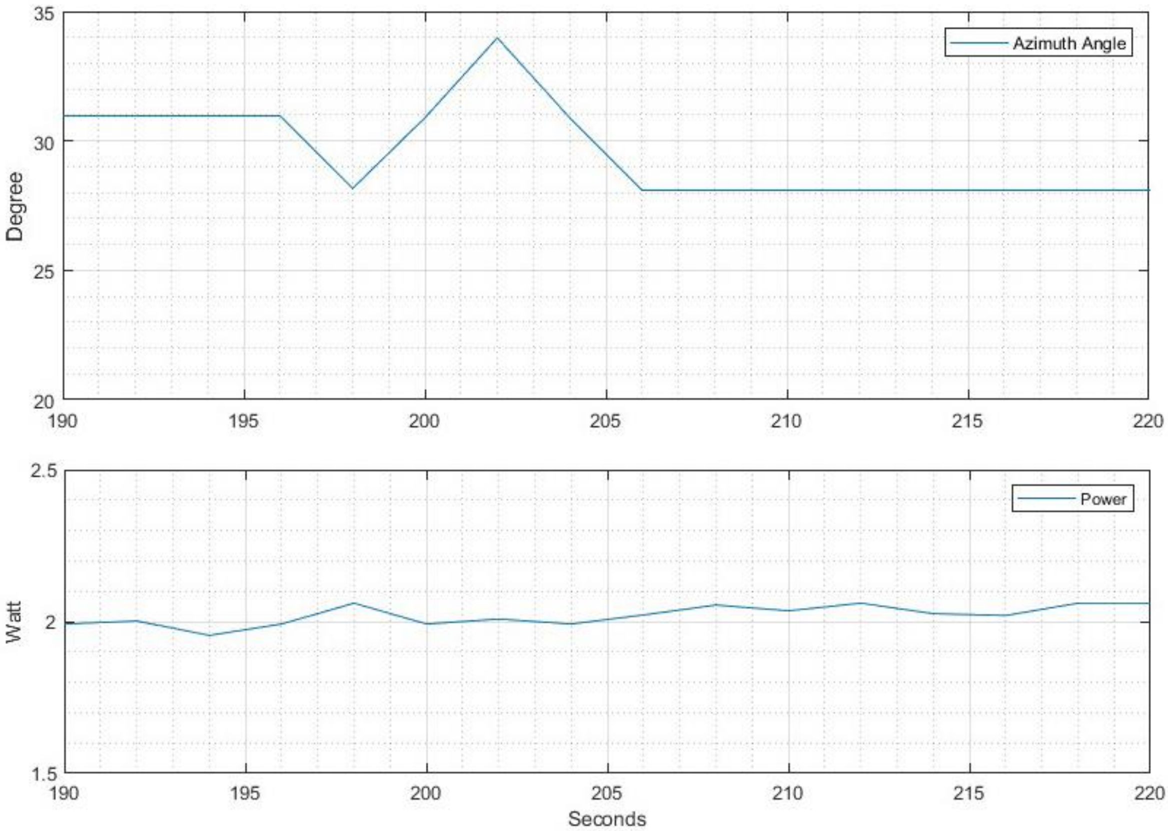


Figure 28: Closer view of Azimuth Angle while tracking (Cycle-2)

In Figure 28, the azimuth motor reversed for 3° and forwarded again 6° just like before. This time, the power was maximum at 198th second when the azimuth angle was about 28°. So, from 31° position the panel reversed back to 28° azimuth position.

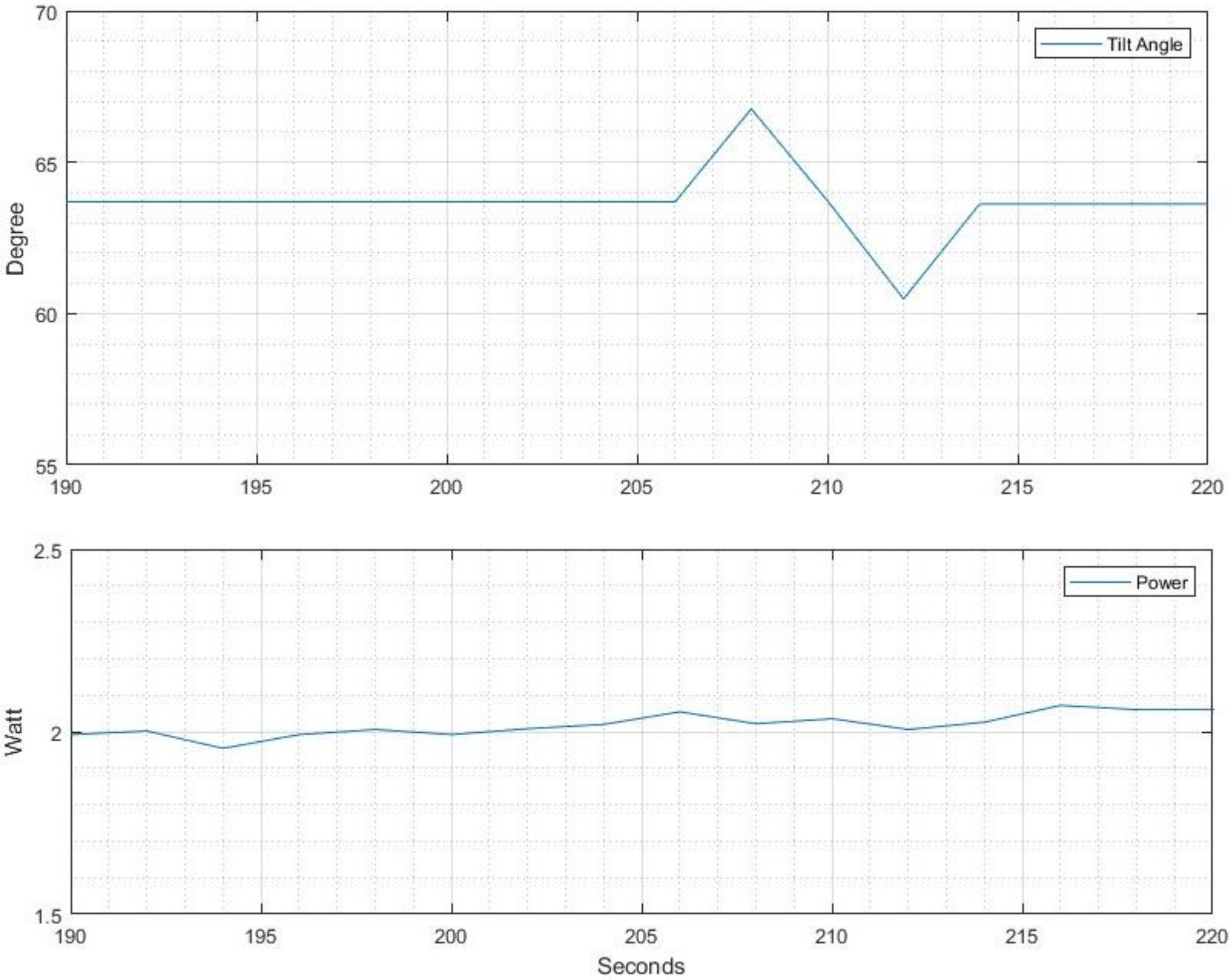


Figure 29: Closer view of Tilt Angle while tracking (Cycle-2)

In Figure 29, at 206th second tilt angle tracking started and just like before tilt motor reversed 3° and forwarded 6°. And the power was maximum at the starting point which was 63.7° tilt position. So, the panel went back to 63.7° and remained there.

At the starting point, the panel had an output power of 1.6 Watt and after optimizing and tracking, the power reached up to 2.1 watt, which indicates a positive sign towards good optimization and tracking.

4.6 Storm mode test

As it was not possible to create a storm in the lab, wind speed equal or greater than 6 m/s was set as storm limit. It was not difficult to create 6 m/s wind speed by rotating the anemometer by hand. During the test the anemometer was being rotated by hand for the whole time. In addition, in the algorithm the storm mode was supposed to be enabled for 10 minutes once engaged, but the time is reduced to 30 seconds for the test. Having no effect in azimuth angle of storm mode, only tilt angle is presented in the result.

Result:

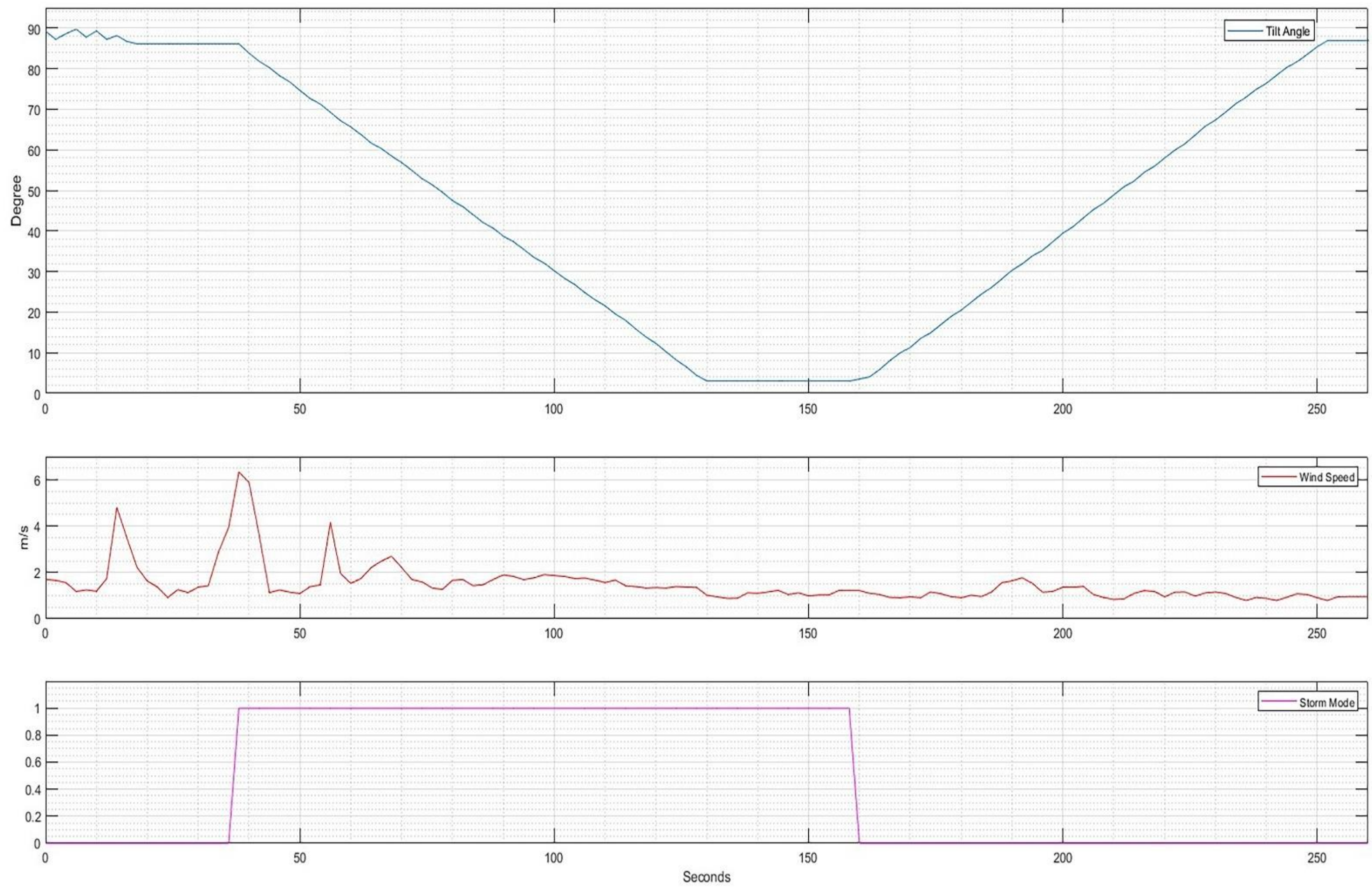


Figure 30: Storm mode test result

In Figure 30, the wind speed reached over 6 m/s at 38th second. The storm mode is enabled instantly, and the panel starts going towards 0° tilt position. At 130th second tilt angle becomes 0° and the panel remained there for 30 seconds. After exactly 30 seconds at 160 second mark storm mode is disabled as the wind speed was below 6 m/s. Then the panel started going back to its position where it was before the storm. The tilt angle was about 88° before the storm and after the storm it goes back at 87.8° tilt position. Which concludes that the algorithm is working as it should.

5 Conclusion and further work

The pyranometer was not giving any reading with the light source used for the test. But it was tested that the meter works on direct sunlight.

Since the H-Bridge didn't employ a freewheeling diode or capacitor, switching may cause a high voltage spike. As a result, the life of the relays will shorten. Therefore, this project demands for a better H-Bridge design.

The power measurement reading was very inconsistent. The design and construction of a suitable power measurement card is required that can withstand the voltage and current of all 8 panels 136 V(maximum) and 23.52 A (maximum) respectively.

Induction sensors should be mounted at proper positions of the rig and initial angles has to be calculated.

It is recommended that the Wago 750-404/000-003 frequency module be replaced with Wago 750-404/000-000 up-down counters. An up-down counter module will reduce the complexity of the motor positioning and orientation system.

The sun's position calculation has to be incorporated with the program.

Some programs are written in a complex way which can be simplified. Also, Optimizing, Tracing mode and Storm mode are combined in a single program. They can be written as individual program and can be called from one main program.

Even though an HMI is created within e!cockpit software, a better HMI can be designed. One useful feature absents in this design and can be added is the Manual Control maneuverability.

A mechanical safety system has to be developed which will prevent the rig from 360° rotation or hitting any obstacles in case the program or Induction sensors fail.

For tracking, a Zig zag algorithm proposed by an earlier thesis [3] is used. One problem with this algorithm is, it takes longer to optimize. Designing a better algorithm will enhance the performance of the whole system.

Reference

1. Codesys Online Help [Online]. Available: https://help.codesys.com/webapp/_cds_struct_project_creation;product=codesys;version=3.5.1

2. Wago IO System [Online]. Available: https://wago.com/global/i-o-systems

3. Latitude Based Model for Tilt Angle Optimization [Online]. Available: https://www.sciencedirect.com/science/article/pii/S1876610213017451

4. B. Nilsen, "Solar angle optimizer," master's thesis, UiT Norways Artic University Narvik, 2021.

5. Mathias Skjelbred, "Solar angle optimizer," master's thesis, UiT Norways Artic University Narvik, 2022.

Appendix

Wiring List

Pin Name/Number	Connected to
Motor 1, +24V	H-Bridge (Motor1 +)
Motor 1, 0 V	H-Bridge (Motor 1 -)
Hall Sensor 1, Pin 1: 0 V	PLC 750-404/1 (0 V)
Hall Sensor 1, Pin2: +24 V	PLC 750-404/1 (24 V)
Hall Sensor 1, Pin3: Signal	PLC 750-404/1 (CLK)
Motor 2, +24V	H-Bridge (Motor2 +)
Motor 2, 0 V	H-Bridge (Motor 2 -)
Hall Sensor 2, Pin 1: 0 V	PLC 750-404/2 (0 V)
Hall Sensor 2, Pin2: +24 V	PLC 750-404/2 (24 V)
Hall Sensor 2, Pin3: Signal	PLC 750-404/2 (CLK)
Induction Sensor 1, 24V	PLC (24 V)
Induction Sensor 1, Signal	PLC 750-455/1 (A1)
Induction Sensor 2, 24V	PLC (24 V)
Induction Sensor 2, Signal	PLC 750-455/1 (A2)
Induction Sensor 3, 24V	PLC (24 V)
Induction Sensor 3, Signal	PLC 750-455/1(A3)
Induction Sensor 4, 24V	PLC (24 V)
Induction Sensor 4, Signal	PLC 750-455/1 (A4)
Pyranometer, +	PLC 750-468 (A1)
Pyranometer, -	PLC 750-468 (GND)
Anemometer, +24V	PLC (24 V)
Anemometer, 0V	PLC (0 V)
Anemometer, Signal	PLC 750-468 (A2)
H-Bridge, 24V +	24 V Power source (+24 V)
H-Bridge, 24V -	24 V Power source (GND)
H-Bridge, FWD_SIG1 (1)	PLC 750-504 (D1)
H-Bridge, FWD_SIG1 (2)	PLC 750-504 (V0)
H-Bridge, REV_SIG1 (1)	PLC 750-504 (D2)
H-Bridge, REV_SIG1 (2)	PLC 750-504 (V0)
H-Bridge, FWD_SIG2 (1)	PLC 750-504 (D3)
H-Bridge, FWD_SIG2 (2)	PLC 750-504 (V0)
H-Bridge, REV_SIG2 (1)	PLC 750-504 (D4)
H-Bridge, REV_SIG2 (2)	PLC 750-504 (V0)

PV out	Current measuring device
PV out	Voltage measuring device
Voltage measuring device, Signal	PLC 750468/2 (A1)
Current measuring device, Signal	PLC 750468/2 (A2)

Table 3: Wiring list

Codes

Initializing

```
PROGRAM Initialising
VAR

	CL1,CL2: DWORD;
	State1,State2,Pstate1,Pstate2 : DWORD:=0;
	J,X,H,Counter1,Counter2: REAL:=0;
	WindSpeed,IS1,IS2, IS3, IS4: REAL;
	Irrad,AM, PM: REAL;
	AziDeg,TltDeg,Deg1,Deg2,RefDeg :REAL:=0;
	SFV: REAL:=0.0003;  // voltage scaling factor
	Delay:TON;
	Z,I,Power,P0,P1,P2,P3,P4,P5:REAL:=0;
	M1_FWD, M1_REV: BOOL:=FALSE;
	M2_FWD, M2_REV: BOOL:=FALSE;
	LStorm,LOAzi,LOTlt,LHAzi,LHTlt:BOOL:=FALSE;
	Storm:BOOL;
	Voltage, Current,Pmax, P2Max: REAL;
	FbDatalogger1:FbDatalogger;
	xActivate:BOOL:=TRUE;
	aValues:ARRAY[1..MAX_CHANNELS] OF REAL;
	xEvent:BOOL;
	log_xReady:BOOL;
	log_sStatus: STRING.
	log_oStatus: WagoSysErrorBase.FbResult;
	typConfigParameters:typConfigdatalogger;
	xInit:BOOL:=TRUE;
	//M1= Azimuth Motor  M2= Tilt Motor
END_VAR


	typConfigParameters.bDatalogger_type:=3; //Dataplotter format
	typConfigParameters.sPath:='/media/sd/0Initialising1'; //Path
	typConfigParameters.xCyclicLogging:=TRUE;
	typConfigParameters.bInterval :=3; //Interval
	typConfigParameters.uiIntervalFactor:=1; // write every 1 seconds
```

```
	//Initialize channels
	typConfigParameters.atypChannelConfig[1].xChannelExists:=TRUE;
	typConfigParameters.atypChannelConfig[1].sChannelName:='AzimuthAngle
(Degree)';
	typConfigParameters.atypChannelConfig[2].xChannelExists:=TRUE;
	typConfigParameters.atypChannelConfig[2].sChannelName:='TiltAngle (Degree)';
	typConfigParameters.atypChannelConfig[3].xChannelExists:=TRUE;
	typConfigParameters.atypChannelConfig[3].sChannelName:='Power (Milli Watt)';
aValues[1]:= Deg1;
aValues[2]:= Deg2;
aValues[3]:= I;
FbDatalogger1(
	xActivate:=xActivate ,
	aValues:=aValues ,
	xEvent:=xEvent ,
	typConfigParameters:=typConfigParameters ,
	oStatus=> log_oStatus ,
	sStatus=> log_sStatus ,
	xReady=> log_xReady );

PM:= IoConfig_Globals_Mapping.PM;
AM:= IoConfig_Globals_Mapping.AM;
IS1:=IoConfig_Globals_Mapping.IS1;
IS2:=IoConfig_Globals_Mapping.IS2;
IS3:=IoConfig_Globals_Mapping.IS3;
IS4:=IoConfig_Globals_Mapping.IS4;
CL1:= IoConfig_Globals_Mapping.CL1;
CL2:= IoConfig_Globals_Mapping.CL2;


State1 := CL1;
IF State1<>Pstate1 THEN
		Counter1:= Counter1+1;
		ELSE Counter1:= Counter1;
END_IF
Pstate1:=State1;
IF M1_REV=TRUE THEN Deg1:= 0.05037287*Counter1;
ELSIF M1_FWD= TRUE THEN Deg1:= 0.05137287*Counter1; END_IF

State2 := CL2;
IF State2<>Pstate2 THEN
		Counter2:= Counter2+1;
		ELSE Counter2:= Counter2;
END_IF
Pstate2:=State2;
Deg2:= 0.05337287*Counter2;
```

```
//Initialising Azimuth Angle
IF I=0 AND IS1>32766 THEN M1_FWD:=FALSE; M1_REV:=TRUE;
	ELSIF I=0 AND IS1<32767	THEN  M1_REV:=FALSE; M1_FWD:=FALSE; I:=1;
	Deg1:=15; //A predefined Azimuthal angle. ** Can be set depending upon actual position on site
	 counter1:=0;
END_IF

//Initialising Tilt Angle
IF I=1 AND IS3>32766 THEN M2_FWD:=FALSE; M2_REV:=TRUE;
	ELSIF I=1 AND IS3<32767 THEN M2_REV:=FALSE; M2_FWD:=FALSE; I:=2;
 Deg2:=90; //At this initial position the panel will be almost vertical. So the Tilt angle is defined as 90 degree
 counter2:=0;
END_IF

//Other operation mode (Moving forward as an example in this case)
IF I=2 AND IS2>32766 AND Deg1<70 THEN
	 M1_REV:=FALSE; M1_FWD:=TRUE; //Azimuthal rotation is limited to 330 degree as protection
ELSIF I=2 AND (IS2<32767 OR Deg1>70) THEN M1_FWD:=FALSE; M1_REV:=FALSE; I:=3;
END_IF

//Returning to initial position
IF I=3 AND IS1>32766 THEN M1_FWD:=FALSE; M1_REV:=TRUE;
	ELSIF I=3 AND IS1<32767	THEN   M1_REV:=FALSE;  M1_FWD:=FALSE;   Deg1:=15; I:=4;
	ELSIF I=4 AND IS3>32766 THEN M2_FWD:=FALSE; M2_REV:=TRUE;
	ELSIF I=4 AND IS3<32767 THEN M2_REV:=FALSE; M2_FWD:=FALSE; Deg2:=90;
END_IF
```

Optimization, Tracking and Storm Mode

```
PROGRAM PLC_PRG
VAR
	CL1,CL2: DWORD;
	State1,State2,Pstate1,Pstate2 : DWORD:=0;
	J,X,H,Counter1,Counter2: REAL:=0;
	WindSpeed,IS1,IS2, IS3, IS4: REAL;
	Irrad,AM, PM: REAL;
	AziDeg,TltDeg,Deg1,Deg2,RefDeg :REAL:=0;
	SFV: REAL:=0.0003;  // voltage scaling factor
	Delay:TON;
	Z,I,Power,P0,P1,P2,P3:REAL:=0;
```

```
	M1_FWD, M1_REV: BOOL:=FALSE;
	M2_FWD, M2_REV: BOOL:=FALSE;
	LStorm,LOAzi,LOTlt,LHAzi,LHTlt:BOOL:=FALSE;
	Storm:BOOL;
	Voltage, Current,Pmax, P2Max: REAL;
	FbDatalogger1:FbDatalogger;
	xActivate:BOOL:=TRUE;
	aValues:ARRAY[1..MAX_CHANNELS] OF REAL;
	xEvent:BOOL;
	log_xReady:BOOL;
	log_sStatus: STRING;
	log_oStatus: WagoSysErrorBase.FbResult;
	typConfigParameters:typConfigdatalogger;
	xInit:BOOL:=TRUE;
END_VAR

	//DataLogger
	typConfigParameters.bDatalogger_type:=3; //Dataplotter format
	typConfigParameters.sPath:='/media/sd/Storm2'; //Path
	typConfigParameters.xCyclicLogging:=TRUE;
	typConfigParameters.bInterval :=3; //Interval
	typConfigParameters.uiIntervalFactor:=2; // write every 2 seconds
	//Channel Configuration
	typConfigParameters.atypChannelConfig[1].xChannelExists:=TRUE;
	typConfigParameters.atypChannelConfig[1].sChannelName:='AzimuthAngle
(Degree)';
	typConfigParameters.atypChannelConfig[2].xChannelExists:=TRUE;
	typConfigParameters.atypChannelConfig[2].sChannelName:='TiltAngle (Degree)';
	typConfigParameters.atypChannelConfig[3].xChannelExists:=TRUE;
	typConfigParameters.atypChannelConfig[3].sChannelName:='Power (Milli Watt)';
	typConfigParameters.atypChannelConfig[4].xChannelExists:=TRUE;
	typConfigParameters.atypChannelConfig[4].sChannelName:='Wind Speed (m/s)';
	typConfigParameters.atypChannelConfig[5].xChannelExists:=TRUE;
	typConfigParameters.atypChannelConfig[5].sChannelName:='I';
aValues[1]:= AziDeg;
aValues[2]:= TltDeg;
aValues[3]:= Power;
aValues[4]:= WindSpeed;
aValues[5]:= I;
FbDatalogger1(
	xActivate:=xActivate ,
	aValues:=aValues ,
	xEvent:=xEvent ,
	typConfigParameters:=typConfigParameters ,
	oStatus=> log_oStatus ,
	sStatus=> log_sStatus ,
	xReady=> log_xReady );
```

```
//Sensors configuration
PM:= IoConfig_Globals_Mapping.PM; //Pyranometer
AM:= IoConfig_Globals_Mapping.AM; //Anemometer
IS1:=IoConfig_Globals_Mapping.IS1; //4 Induction sensors
IS2:=IoConfig_Globals_Mapping.IS2;
IS3:=IoConfig_Globals_Mapping.IS3;
IS4:=IoConfig_Globals_Mapping.IS4;
CL1:= IoConfig_Globals_Mapping.CL1; //2 pulse counter for motor positioning
CL2:= IoConfig_Globals_Mapping.CL2;

WindSpeed:=AM*SFV*6.0975; //Sensitivity of Anemometer is 0.164 Vs/m
Irrad:=(SFV*PM)/49.5; //Sensitivity of Pyranometer is 49.5
Voltage:= SFV*100*IoConfig_Globals_Mapping.Voltage;
Current:= SFV*2.5*IoConfig_Globals_Mapping.Current*0.9;
Power:= Voltage*Current*1000;

State1 := CL1;
IF State1<>Pstate1 THEN
            Counter1:= Counter1+1;
            //ELSE Counter1:= Counter1;
END_IF
Pstate1:=State1;
IF M1_REV=TRUE THEN Deg1:= 0.05037287*Counter1;
ELSIF M1_FWD= TRUE THEN Deg1:= 0.05137287*Counter1; END_IF

State2 := CL2;
IF State2<>Pstate2 THEN
            Counter2:= Counter2+1;
            //ELSE Counter2:= Counter2;
END_IF
Pstate2:=State2;
Deg2:= 0.05337287*Counter2;

//For HMI
IF I>-1 AND I<5 THEN LOAzi:= TRUE; ELSE LOAzi:=FALSE; END_IF
IF I>4 AND I<10 THEN LOTlt:= TRUE; ELSE LOTlt:=FALSE; END_IF
IF I>9 AND I<12 THEN LHAzi:= TRUE; ELSE LHAzi:=FALSE; END_IF
IF I>11 AND I<14 THEN LHTlt:= TRUE; ELSE LHTlt:=FALSE; END_IF


//STORM MODE
IF WindSpeed>5 THEN I:=100; Delay(IN:=FALSE); END_IF

IF I=100 AND X=0 THEN LStorm:=TRUE; M1_FWD:= FALSE; M1_REV:=FALSE;
M2_FWD:=FALSE; M2_REV:=FALSE; Counter2:=0; Deg2:=0;  RefDeg:=TltDeg; X:=1;
```

```
ELSIF I=100 AND X=1 AND IS4>32766 AND Deg2<(80-RefDeg) THEN M2_REV:=FALSE;
        M2_FWD:=TRUE;
ELSIF I=100 AND X=1 AND IS4>32766 AND Deg2>(80-RefDeg) THEN M2_REV:=FALSE;
        M2_FWD:=FALSE; Delay(IN:=TRUE, PT:=T#30S); IF NOT(Delay.Q) THEN RETURN;
END_IF Delay(IN:=FALSE);
                TltDeg:=TltDeg+Deg2; Counter2:=0; Deg2:=0; X:=0; J:=2; LStorm:=FALSE;
I:=150;
END_IF

IF WindSpeed<5 AND J=2 AND IS3>32766 AND (TltDeg-RefDeg)>Deg2 THEN
        M2_FWD:=FALSE; M2_REV:=TRUE;
ELSIF WindSpeed<5 AND J=2 AND IS3>32766 AND (TltDeg-RefDeg)<Deg2 THEN
        M2_FWD:=FALSE; M2_REV:=FALSE; TltDeg:=TltDeg-Deg2; Counter2:=0; Deg2:=0;
I:=10; J:=0;
END_IF

//State 0
IF IS1>32766 AND I=0 AND WindSpeed<5 THEN
        IF I=0 AND Z=0 THEN P0:= Power; Z:=1;
        ELSIF I=0 AND Z=1 AND Deg1<3 THEN M1_FWD:= FALSE; M1_REV:= TRUE; P1:=Power;
        ELSIF I=0 AND Z=1 AND Deg1>3 THEN M1_FWD:= FALSE; M1_REV:= FALSE;
AziDeg:=AziDeg-Deg1; I:=1;
ELSIF Windspeed>5 THEN I:=100; END_IF
END_IF

//State 1
IF IS2>32766 AND I=1 AND WindSpeed<5 AND P1>P0 THEN Counter1:=0; Deg1:=0; I:=0; Z:=0;
ELSIF IS2>32766 AND I=1 AND WindSpeed<5 AND P1=P0 THEN Counter1:=0; Deg1:=0; I:=0;
Z:=0;
ELSIF IS2>32766 AND I=1 AND WindSpeed<5 AND P0>P1 THEN Counter1:=0; Deg1:=0; I:=2;
        Z:=0;
ELSIF WindSpeed>5 THEN I:=100;
END_IF

//State 2
IF IS1>32766 AND I=2 AND WindSpeed<5 THEN
        IF I=2 AND Z=0 THEN P0:= Power; Z:=1;
        ELSIF I=2 AND Z=1 AND Deg1<3 THEN M1_REV:= FALSE; M1_FWD:= TRUE; P1:=Power;
        ELSIF I=2 AND Z=1 AND Deg1>3 THEN M1_FWD:= FALSE; M1_REV:= FALSE;
AziDeg:=AziDeg+Deg1; I:=3; Counter1:=0; Deg1:=0;
ELSIF Windspeed>5 THEN I:=100; END_IF
END_IF

//State3
IF IS2>32766 AND I=3 AND WindSpeed<5 AND P1>P0 THEN I:=2; Z:=0;
ELSIF IS2>32766 AND I=3 AND WindSpeed<5 AND P1=P0 THEN I:=2; Z:=0;
ELSIF IS2>32766 AND I=3 AND WindSpeed<5 AND P0>P1 THEN I:=4;    Z:=0;
```

```
ELSIF WindSpeed>5 THEN I:=100;
END_IF

//State4
IF IS2>32766 AND I=4 AND WindSpeed<5 AND Deg1<3 THEN  M1_FWD:= FALSE; M1_REV:= TRUE;
ELSIF IS2>32766 AND I=4 AND WindSpeed<5 AND Deg1>3 THEN  M1_FWD:= FALSE; M1_REV:= FALSE; AziDeg:=AziDeg-Deg1; I:=5;     Counter1:=0; Deg1:=0;
END_IF


//State 5
IF IS3>32766 AND I=5 AND WindSpeed<5 THEN
	IF I=5 AND Z=0 THEN P0:= Power; Z:=1;
	ELSIF I=5 AND Z=1 AND Deg2<3 THEN M2_FWD:= FALSE; M2_REV:= TRUE; P1:=Power;
	ELSIF I=5 AND Z=1 AND Deg2>3 THEN M2_FWD:= FALSE; M2_REV:= FALSE; TltDeg:=TltDeg-Deg2; I:=6;
ELSIF Windspeed>5 THEN I:=100; END_IF
END_IF

//State 6
IF IS3>32766 AND I=6 AND WindSpeed<5 AND P1>P0 THEN Counter2:=0; Deg2:=0; I:=5; Z:=0;
ELSIF IS3>32766 AND I=6 AND WindSpeed<5 AND P1=P0 THEN  Counter2:=0; Deg2:=0; I:=5; Z:=0;
ELSIF IS3>32766 AND I=6 AND WindSpeed<5 AND P0>P1 THEN  Counter2:=0; Deg2:=0; I:=7;
	Z:=0;
ELSIF WindSpeed>5 THEN I:=100;
END_IF

//State 7
IF IS3>32766 AND I=7 AND WindSpeed<5 THEN
	IF I=7 AND Z=0 THEN P0:= Power; Z:=1;
	ELSIF I=7 AND Z=1 AND Deg2<3 THEN M2_REV:= FALSE; M2_FWD:= TRUE; P1:=Power;
	ELSIF I=7 AND Z=1 AND Deg2>3 THEN M2_FWD:= FALSE; M2_REV:= FALSE; TltDeg:=TltDeg+Deg2; I:=8; Counter2:=0; Deg2:=0;
ELSIF Windspeed>5 THEN I:=100; END_IF
END_IF

//State8
IF IS4>32766 AND I=8 AND WindSpeed<5 AND P1>P0 THEN  I:=7; Z:=0;
ELSIF IS4>32766 AND I=8 AND WindSpeed<5 AND P1=P0 THEN  I:=7; Z:=0;
ELSIF IS4>32766 AND I=8 AND WindSpeed<5 AND P0>P1 THEN  I:=9;     Z:=0;
ELSIF WindSpeed>5 THEN I:=100;
END_IF

//State9
```

```
IF IS4>32766 AND I=9 AND WindSpeed<5 AND Deg2<3 THEN  M2_FWD:= FALSE; M2_REV:=
TRUE;
ELSIF IS4>32766 AND I=9 AND WindSpeed<5 AND Deg2>3 THEN  M2_FWD:= FALSE;
M2_REV:= FALSE;  Delay(IN:=TRUE, PT:=T#60S); IF NOT(Delay.Q) THEN RETURN; END_IF
Delay(IN:=FALSE); I:=10; TltDeg:=TltDeg-Deg2;     Counter2:=0; Deg2:=0;
END_IF

//Tracking M1
IF I=10 AND WindSpeed<5 THEN
        IF I=10 AND H=0 AND Deg1<1 THEN P0:= Power; H:=1;
        ELSIF I=10 AND H=1 AND  Deg1<3 AND IS1>32766 AND IS2>32766 AND WindSpeed<5
THEN M1_REV:= FALSE; M1_FWD:= TRUE; P1:= Power;
                ELSIF I=10 AND H=1 AND  Deg1>3 AND IS1>32766 AND IS3>32766 AND
WindSpeed<5 THEN M1_REV:= FALSE; M1_FWD:= FALSE; AziDeg:=AziDeg+Deg1; H:=2;
Counter1:=0; Deg1:=0;
        ELSIF I=10 AND H=2 AND  Deg1<6 AND IS1>32766 AND IS2>32766 AND WindSpeed<5
THEN M1_FWD:= FALSE; M1_REV:= TRUE; P2:=Power;
        ELSIF I=10 AND H=2 AND  Deg1>6 AND WindSpeed<5 THEN M1_FWD:= FALSE;
M1_REV:= FALSE; AziDeg:=AziDeg-Deg1; I:=11; H:=0; Counter1:=0; Deg1:=0;
  ELSIF WindSpeed>5 THEN I:=100;
 END_IF;
        P2Max:= MAX(P0,(MAX(P1,P2)));
END_IF

IF I=11 AND P2Max=P2 AND WindSpeed<5 THEN M1_FWD:= FALSE; M1_REV:= FALSE;  P0:=0;
P1:=0; P2:=0; P3:=0; Counter1:=0; Deg1:=0; I:=12;

        ELSIF I=11 AND P2Max = P0 AND WindSpeed<5 AND Deg1<3 THEN M1_REV:= FALSE;
M1_FWD:= TRUE;
                ELSIF I=11 AND P2Max = P0 AND WindSpeed<5 AND Deg1>3 THEN M1_REV:=
FALSE; M1_FWD:= FALSE; AziDeg:=AziDeg+Deg1;  P0:=0; P1:=0; P2:=0; P3:=0; Counter1:=0;
Deg1:=0; I:=12;
                        ELSIF I=11 AND P2Max= P1 AND WindSpeed<5 AND Deg1<6 THEN
M1_REV:= FALSE; M1_FWD:= TRUE;
                        ELSIF I=11 AND P2Max= P1 AND WindSpeed<5 AND Deg1>6 THEN
M1_REV:= FALSE; M1_FWD:= FALSE; AziDeg:=AziDeg+Deg1;  P0:=0; P1:=0; P2:=0; P3:=0;
Counter1:=0; Deg1:=0; I:=12;
ELSIF WindSpeed>5 THEN I:=100;
END_IF

//Tracking M2
IF I=12 AND WindSpeed<5 THEN
        IF I=12 AND H=0 AND Deg2<1 THEN P0:= Power; H:=1;
        ELSIF I=12 AND H=1 AND  Deg2<3 AND IS3>32766 AND IS4>32766 AND WindSpeed<5
THEN M2_REV:= FALSE; M2_FWD:= TRUE; P1:= Power;
```

```
ELSIF I=12 AND H=1 AND  Deg2>3 AND IS3>32766 AND IS4>32766 AND
WindSpeed<5 THEN M2_REV:= FALSE; M2_FWD:= FALSE; TltDeg:=TltDeg+Deg2; H:=2;
Counter2:=0; Deg2:=0;
ELSIF I=12 AND H=2 AND  Deg2<6 AND IS3>32766 AND IS4>32766 AND WindSpeed<5
THEN M2_FWD:= FALSE; M2_REV:= TRUE; P2:=Power;
ELSIF I=12 AND H=2 AND  Deg2>6 AND WindSpeed<5 THEN M2_FWD:= FALSE;
M2_REV:= FALSE; TltDeg:=TltDeg-Deg2; I:=13; H:=0; Counter2:=0; Deg2:=0;
ELSIF WindSpeed>5 THEN I:=100;
END_IF;
P2Max:= MAX(P0,(MAX(P1,P2)));
END_IF


IF I=13 AND P2Max=P2 AND WindSpeed<5 THEN M2_FWD:= FALSE; M2_REV:= FALSE;
Delay(IN:=TRUE, PT:=T#60S); IF NOT(Delay.Q) THEN RETURN; END_IF Delay(IN:=FALSE);
P0:=0; P1:=0; P2:=0; P3:=0; Counter2:=0; Deg2:=0; I:=10;
ELSIF I=13 AND P2Max = P0 AND WindSpeed<5 AND Deg2<3 THEN M2_REV:=
FALSE; M2_FWD:= TRUE;
ELSIF I=13 AND P2Max = P0 AND WindSpeed<5 AND Deg2>3 THEN M2_REV:=
FALSE; M2_FWD:= FALSE;  Delay(IN:=TRUE, PT:=T#60S); IF NOT(Delay.Q) THEN RETURN;
END_IF Delay(IN:=FALSE); P0:=0; P1:=0; P2:=0; P3:=0; TltDeg:=TltDeg+Deg2; Counter2:=0;
Deg2:=0; I:=10;
ELSIF I=13 AND P2Max= P1 AND WindSpeed<5 AND Deg2<6 THEN M2_REV:=
FALSE; M2_FWD:= TRUE;
ELSIF I=13 AND P2Max= P1 AND WindSpeed<5 AND Deg2>6 THEN M2_REV:=
FALSE; M2_FWD:= FALSE;  Delay(IN:=TRUE, PT:=T#60S); IF NOT(Delay.Q) THEN RETURN;
END_IF Delay(IN:=FALSE); P0:=0; P1:=0; P2:=0; P3:=0; TltDeg:=TltDeg+Deg2; Counter2:=0;
Deg2:=0; I:=10;
ELSIF WindSpeed>5 THEN I:=100;
END_IF
```

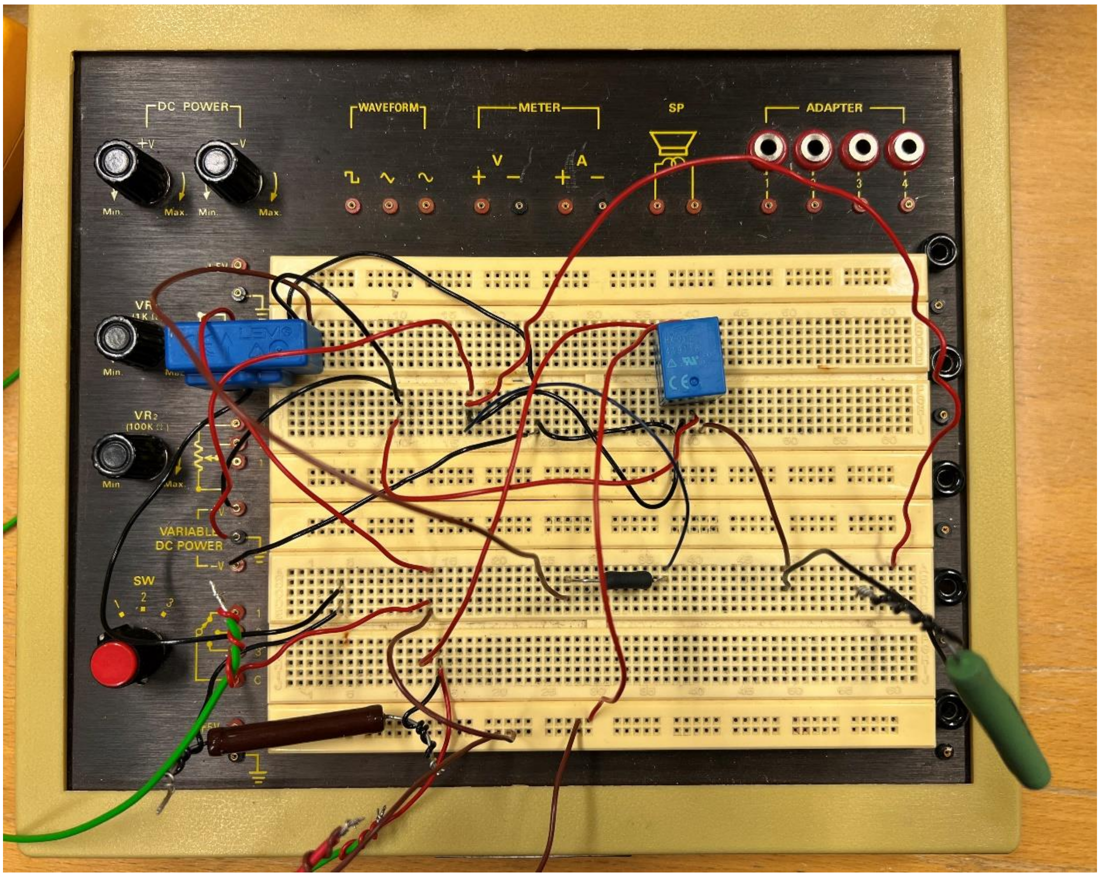


Figure 1: Test setup for Power measuring PCB

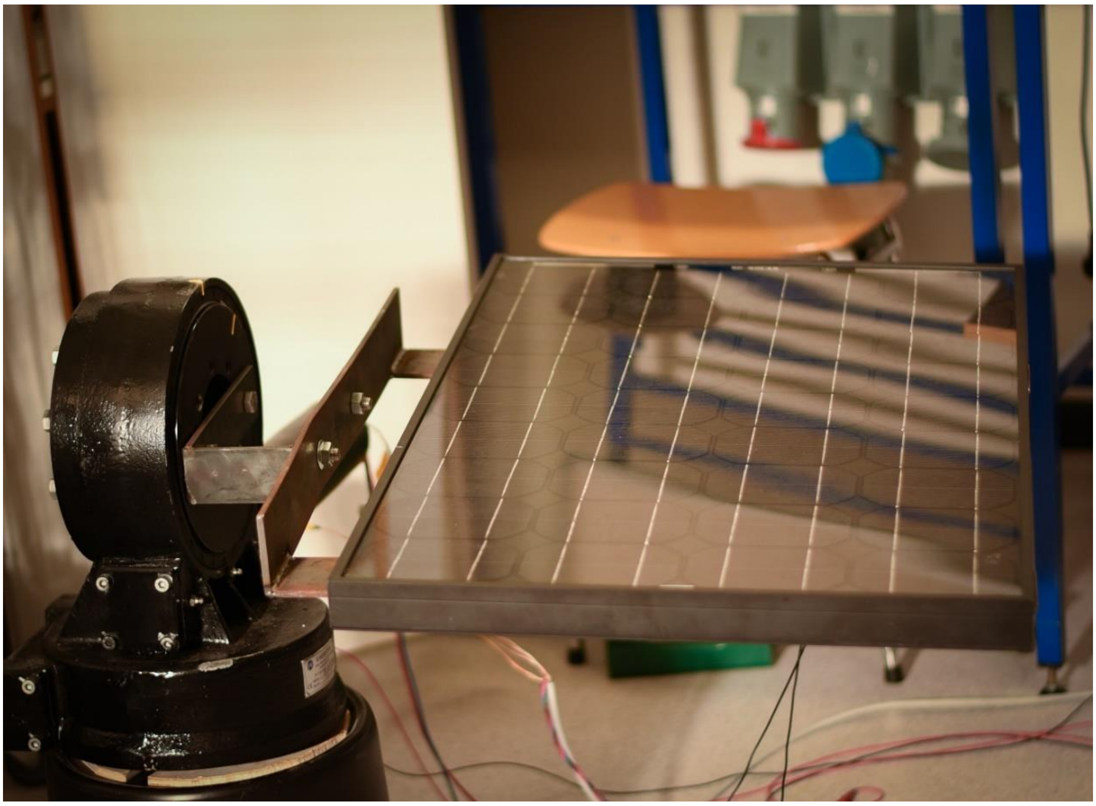
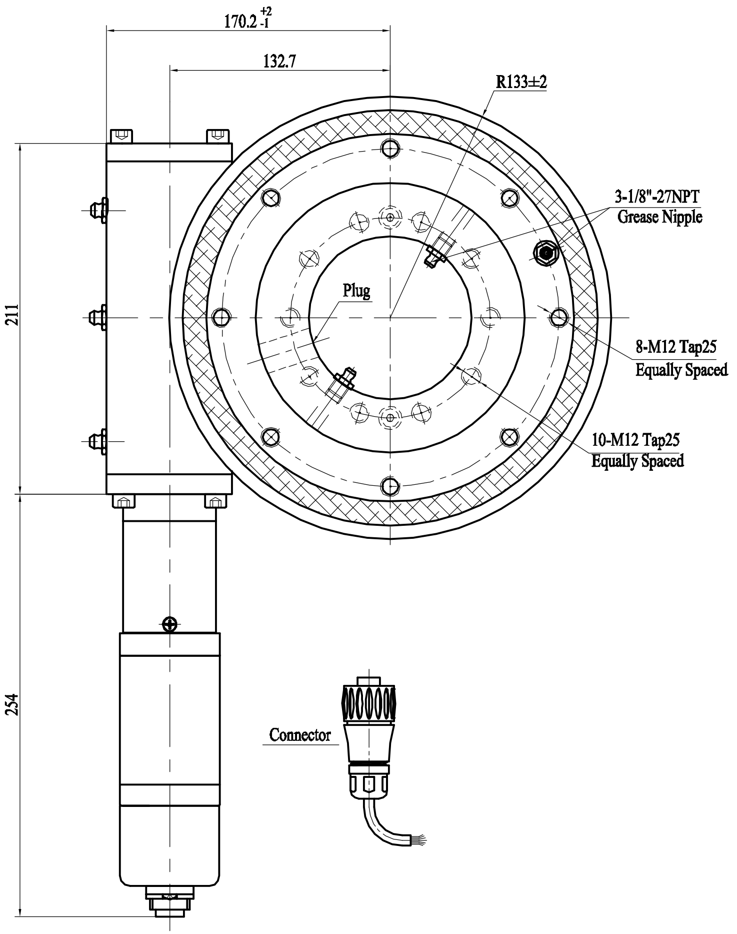
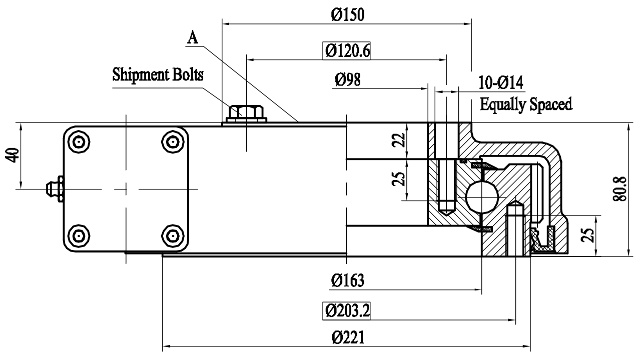
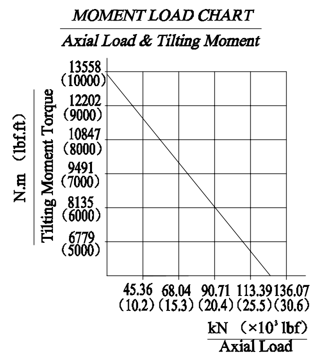


Figure 2: Panel position during storm mode

HOURGLASS WORM SLEWING DRIVE





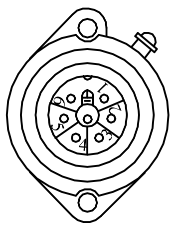


Slewing Drive Performance Data

Rated Output Speed	0.04 rpm	
Rated Output Torque	722.7 N.m	533.4 lbf.ft
Tilting Moment Torque（Max.）	13500 N.m	9957 lbf.ft
Holding Torque	10400 N.m	7671 lbf.ft
Axial Load（Max.）	133 kN	29900 lbf
Radial Load（Max.）	53 kN	11915 lbf
Ratio of Worm Gear	73:1	
Tracking Precision	≤ 0.2 °	

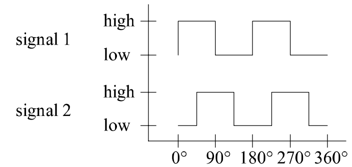
24VDC Planetary Reducer Motor Performance Data（24H/30/33）

Rated Voltage	24 VDC
Rated Current	＜1.2 A
Gear Ratio	575:1
Noises	≤60 dB
IP Class	IP54
Temperature	-40 - +80° C



MAGNETIC PULSE GENERATOR DATA

Output type		voltage output
Pull-up resistor	-	yes
Output signal	-	2 square wave signals
Phase quadrature	-	90°
Impulses per revolution	ppr	2,channels A and B
Operating voltage	VDC	UN=12(5… 24)
Operating current	mA	max. 12 (U=12V)
Deviation of pulse width	-	max. 15°
Deviation of phase shift	-	max. 15°
Output voltage(low level)	VDC	max. 0.4 (20mA)
Signal rise time	ns	85
Signal decay time	ns	60
Operation temperature	℃	-40 … +85



Wire Define:

Pin 1	motor －
Pin 2	motor ＋
Pin 3	hall GND
Pin 4	hall ＋12V
Pin 5	hall A
Pin 6	hall B
Pin E	Ground

Note:1.Please drive the Motor and Hall sensors with separate power. Otherwise, the Hall sensors may be damaged by the electric impact caused by motor's frequent start.
2.Side A facing up when mounted.

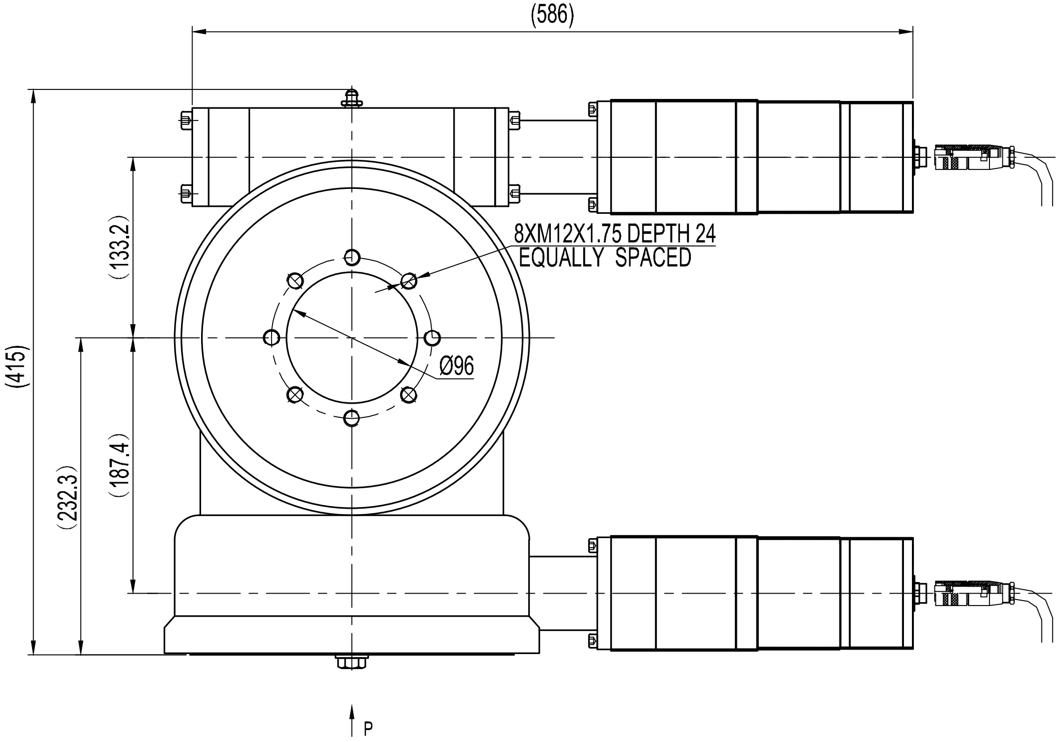
REV	DATE	REVISER	DESCRIPTION

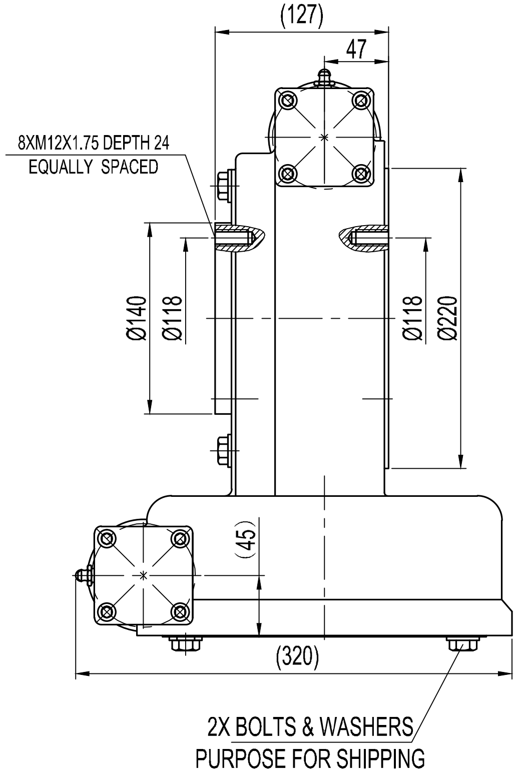
DESIGNED BY	XZL	10-06-2014
CHECKED BY	WDX	10-06-2014
APPROVED BY	Andy	10-06-2014

H-FANG JIANGYIN HUAFANG NEW ENERGY HI-TECH EQUIPMENT CO., LTD
www.h-fang.com.cn

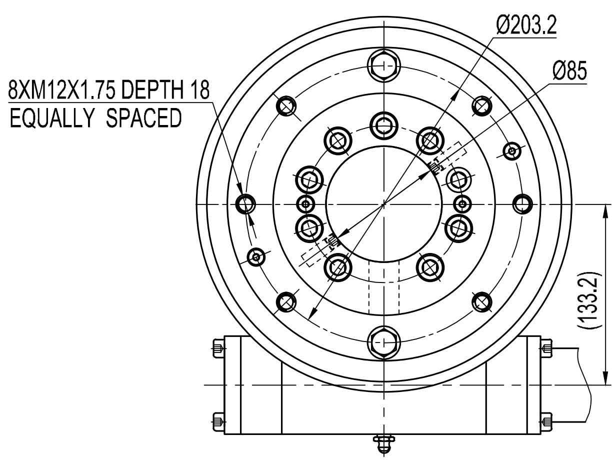
WEIGHT	SCALE	
	1:3	
SIZE	A3	
SHEET	1 / 1	
SYMBOLE ISO		

Title	SLEWING DRIVE	
Model No.	SE7A	
Part No.	73-R-24H.30.33	Rev C





VIEW P



DESIGNED BY	X F	2016/05/20	KMI GROUP www.kinematicsmfg.com	
CHECKED BY	C F	2016/05/20		
APPROVED BY	WMS	2016/05/20		
ALL PROPRIETARY RIGHTS IN THE SUBJECT MATTER HEREOF ARE RESERVED, AND NO PERMISSION IS GRANTED TO REPRODUCE THIS PRINT IN WHOLE OR IN PART, OR TO DISCLOSE ANY OF THE INFORMATION TO OTHERS.	WEIGHT	SCALE: NTS	SLEWING DRIVE	
SYMBOLE ISO	SIZE: A3	SHEET: 1/1	SDE7D-73MHA-24H01RC-BA160	REV: A
		THE TOLERANCE NOT MENTIONED IS REFERRED TO ISO 2768-vL,CASTING TOLERANCE ISO 8062-CT10		

REV.	DATE	PAGE	REVISER	CHECKED BY	DESCRIPTION
A	2016/05/20	MODEL	XF	CF	RELEASED FOR REVIEW

DESIGNED BY	X F	2016/05/20
CHECKED BY	C F	2016/05/20
APPROVED BY	WMS	2016/05/20

KMI GROUP
www.kinematicsmfg.com

WEIGHT	SCALE
	NTS

SLEWING DRIVE

SYMBOLE ISO	SIZE	A3	SHEET	1/1

SDE7D-73MHA-24H01RC-BA160

REV A

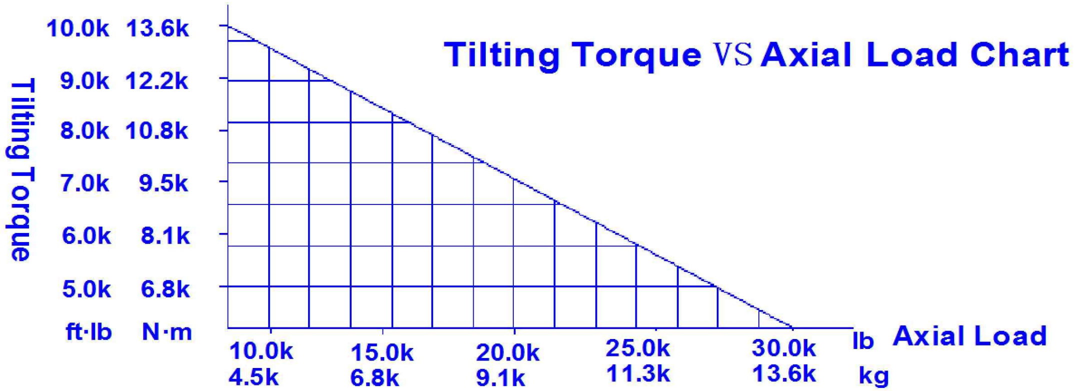
REV.	DATE	PAGE	REVISER	CHECKED BY	DESCRIPTION

SLEWING DRIVES PERFORMANCE DATA

Model Code : SDE7D-73MHA-24H01RC-BA160

Slewing Drive Ratio	73:1	Gearmotor		
Rotating Output Rated Speed	0.1 rpm	Type Code	24H-1560-223-60-V-20S-70	
Efficiency	30%	Rated Voltage	24	VDC
International Protection (IP)	55	Output Speed	7	rpm
Slewing Drive Temperature	－20℃ to＋80℃	Rated Current	5.0	A
Rated Output Torque	1314N·m	Output Power	45.0	w
Max. Output Torque	2628N·m	Motor Rated Speed	1560	rpm
Torsion Stiffness	762Nm/mRad	Output Torque	60	N·m
Bending Stiffness	1083Nm/mRad	Stall Torque	120	N·m

Slewing Drive Loading Data	HA Type			
Normal Output Torque	2,010	N·m	1,483	ft·lb
Max. Output Torque (3 Sec.)	4,020	N·m	2,965	ft·lb
Backwards Holding Torque	10,338	N·m	7,625	ft·lb
Tilting Torque	13,556	N·m	9,999	ft·lb
Static Radial Rating	53.28	kN	11,977	lb
Static Axial Rating	133.20	kN	29,943	lb
Dynamic Radial Rating	27.91	kN	6,274	lb
Dynamic Axial Rating	31.90	kN	7,171	lb



DESIGNED BY	X F	2016/05/20
CHECKED BY	C F	2016/05/20
APPROVED BY	WMS	2016/05/20

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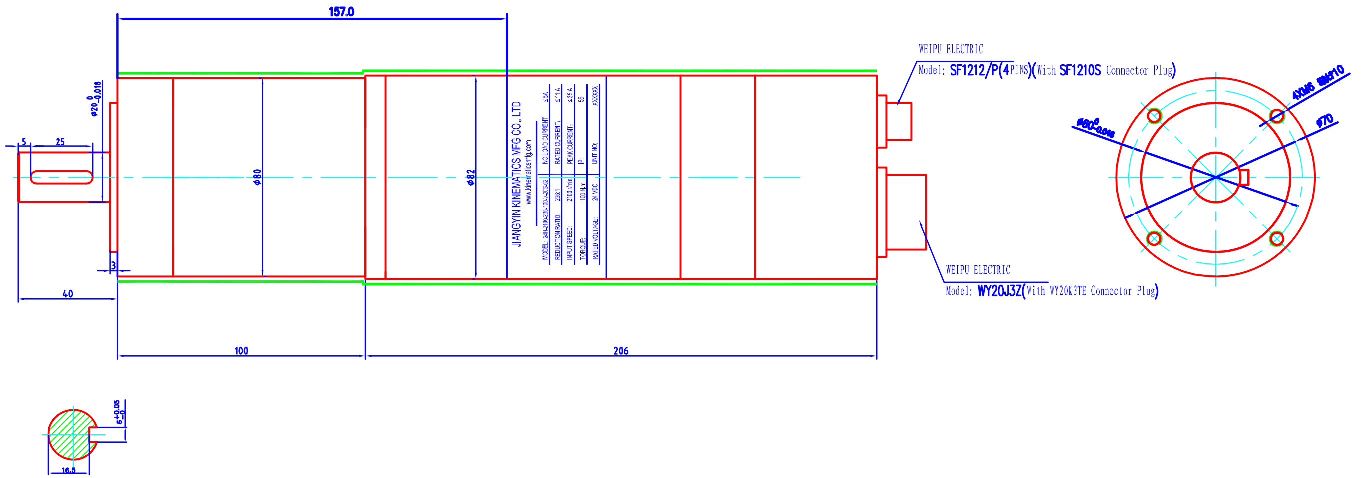
WEIGHT	SCALE
	NTS

SLEWING DRIVE

SYMBOLE ISO	SIZE	A4	SHEET	1/1

SDE7D-73MHA-24H01RC-BA160

REV A



Motor Parameters	
Rated voltage U_N (VDC)	24
No-load speed V_K (RPM)	2250±8%
No-load current I_{NL} (A)	<5
Current I_{RM} (A)	<11
Speed V_{RM} (RPM)	2100±8%
Efficiency η_M (%)	>70
Planetary Reducer Parameters	
Ratio	236: 1
Stage	3
Rated output torque T_{RR} (N.m)	100
Intermittent output torque T_{IR} (N.m)	150
Maximum output torque T_{SR} (N.m)	200
Backlash (arcmin)	16
Efficiency η_R (%)	>70
Hall Parameters	
No. of Hall	2
Hall model	A3282
Hall signal	Open Collector
Other Parameters	
Average life-span (h)	2000h
Noise (dB)	≤65
Environmental temperature T_A (℃)	-40 - 80
IP	55

MAGNETIC PULSE GENERATOR DATA		
Output type	-	voltage output
Pull-up resistor	-	yes
Output signal	-	2 square wave signals
phase quadrature	-	90°
Impulses per revolution	ppr	2,channels A and B
Operating voltage	VDC	UN=12 (5 ... 24)
Operating current	mA	max. 12 (U=12V)
Deviation of pulse width	-	max. 15°
Deviation of phase shift	-	max. 15°
Output voltage(low level)	VDC	max. 0.4 (20mA)
SIGNAL RISE TIME	ns	85
SIGNAL DECAY TIME	ns	60
Operating temperature	℃	-40 ... +85

WY20J3Z Electric Connection:

Pin 1: Motor, 0V (MOTOR INPUT), (Black thick wire inside)
Pin 2: Motor, +24V (MOTOR INPUT), (Red thick wire inside)
Pin 3: Motor, GND (MOTOR INPUT), (Black thick wire inside)

SF1212/P(4 Pins) Electric Connection:

Pin 1: Hall, 0V (HALL INPUT), (Black thin wire inside)
Pin 2: Hall, +12V(5-24) (HALL INPUT), (Red thin wire inside)
Pin 3: Hall, Signal A (HAll OUTPUT,square wave signal)(Green thin wire inside)
Pin 4: Hall, Signal B (HAll OUTPUT,square wave signal)(Yellow thin wire inside)

⚠ ATTENTION

Do not exchange the connection for Hall,0V and Hall,12V!
If you do so, Hall will be destroyed!

DESIGNED BY	WJS 2012.10.27
CHECKED BY	F J 2012.10.27
APPROVED BY	JIM 2012.10.27

KMI GROUP

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WEIGHT	SCALE
	1:1.5

Brushed DC Motor with Hall

SIZE	A3	SHEET

SYMBOLE ISO

THE TOLERANCE NOT MENTIONED IS REFERRED TO ISO 2768-vL

24H-2100-236-100-V-20S-70

REV D

HF140FF

MINIATURE INTERMEDIATE POWER RELAY

File No.:E134517

File No.:R50149131

File No.:CQC10002046173

Features

- 10A switching capability
- 5kV dielectric strength (between coil and contacts)
- Standard:Creepage distance >8mm
- 2.0mm contact gap available
- Sockets available
- Plastic sealed and flux proofed types available
- UL insulation system: Class F available

RoHS compliant

CONTACT DATA

Contact arrangement	2A, 2C
Contact resistance[1)]	50mΩ max.(at 1A 24VDC)
Contact material	$AgSnO_2$, AgNi, AgCdO
Contact rating (Res. load)	10A 250VAC 8A 30VDC
Max. switching voltage	250VAC / 30VDC
Max. switching current	10A
Max. switching power	2500VA / 240W
Mechanical endurance	Standard: 1×10^7 OPS W type(1.5mm): 5×10^5 OPS W type(2.0mm): 3×10^5 OPS
Electrical endurance	Standard type:1×10^5 OPS (10A 250VAC NO or NC,Resistive load, Room temp.,1s on 9s off) 1.5 Gap type:NO 3×10^4 OPS,NC 1×10^4 OPS (10A 250VACResistive load, Room temp.,1s on 9s off) 2.0 Gap type:NO 3×10^4 OPS, (10A 250VAC,Resistive load, Room temp., 1s on 9s off) 1×10^5 OPS (8A 30VDC,NO or NC, Resistive load,Room temp.,1s on 9s off)

Notes: 1) The data shown above are initial values.
2) For plastic sealed type, the venting-hole should be excised in electrical endurance test.

CHARACTERISTICS

Insulation resistance		1000MΩ (at 500VDC)
Dielectric strength	Between coil & contacts	5000VAC 1min
	Between contacts sets	3000VAC 1min
	Between open contacts	Standard:1000VAC 1min W type(1.5mm):2000VAC 1min W type(2.0mm):2500VAC 1min
Surge voltage (between coil & contacts)		10kV (1.2/50 μs)
Operate time (at nomi. volt.)		15ms max.
Release time (at nomi. volt.)		5ms max.
Humidity		5% to 85% RH
Ambient temperature		-40°C to 85°C
Shock resistance	Functional	$98m/s^2$
	Destructive	$980m/s^2$
Vibration resistance		10Hz to 55Hz 1.5mmDA
Termination		PCB
Unit weight		Approx. 18g
Construction		Plastic sealed, Flux proofed

Notes: 1) The data shown above are initial values.
2) Please find coil temperature curve in the characteristic curves below.
3) UL insulation system: Class F, Class B.

COIL DATA

at 23°C

Standard type

Nominal Voltage VDC	Pick-up Voltage VDC max.[1)]	Drop-out Voltage VDC min.[1)]	Max. Voltage VDC[2)]	Coil Resistance Ω
3	2.25	0.3	3.9	17 x (1±10%)
5	3.75	0.5	6.5	47 x (1±10%)
6	4.50	0.6	7.8	68 x (1±10%)
9	5.75	0.9	11.7	160 x (1±10%)
12	9.00	1.2	15.6	275 x (1±10%)
18	13.50	1.8	23.4	620 x (1±10%)
24	18.00	2.4	31.2	1100 x (1±10%)
48	36.00	4.8	62.4	4170 x (1±10%)
60	45.00	6.0	78.0	7000 x (1±10%)

COIL

Coil power	Standard: Approx. 530mW W type(1.5mm): Approx. 800mW W type(2.0mm): Approx. 1.4W

Notes: 1) The data shown above are initial values.
2) Maximum voltage refers to the maximum voltage which relay coil could endure in a short period of time.

COIL DATA

at 23°C

W Type (1.5mm)

Nominal Voltage VDC	Pick-up Voltage VDC max.[2)]	Drop-out Voltage VDC min.[2)]	Max. Voltage VDC[3)]	Coil Resistance Ω
3	2.25	0.3	3.3	11.3 x (1±10%)
5	3.75	0.5	5.5	31 x (1±10%)
6	4.50	0.6	6.6	45 x (1±10%)
9	6.75	0.9	9.9	101 x (1±10%)
12	9.00	1.2	13.2	180 x (1±10%)
18	13.5	1.8	19.8	405 x (1±10%)
24	18.0	2.4	26.4	720 x (1±10%)
48	36.0	4.8	52.8	2880 x (1±10%)
60	45.0	6.0	66.0	4500 x (1±10%)

W Type (2.0mm)

Nominal Voltage VDC	Pick-up Voltage VDC max.[2)]	Drop-out Voltage VDC min.[2)]	Max. Voltage VDC[3)]	Coil Resistance Ω
5	3.75	0.5	5.5	18 x (1±10%)
6	4.50	0.6	6.6	26 x (1±10%)
9	6.75	0.9	9.9	58 x (1±10%)
12	9.00	1.2	13.2	102 x (1±10%)
24	18.0	2.4	26.4	410 x (1±10%)
48	36.0	4.8	52.8	1650 x (1±10%)

Notes: 1) When require pick-up voltage < 75% of nominal voltage, special order allowed.
2) The data shown above are initial values.
3) Maximum voltage refers to the maximum voltage which relay coil could endure in a short period of time.
4) In order to meet the stated product performance, please apply rated voltage to coli.
5) For the CO version whose contact gap is 1.5 mm, the operation voltage ≤85% of rated voltage,the coil resistance tolerance is (1±15%).

SAFETY APPROVAL RATINGS

UL/CUL	Standard	AgNi		10A 250VAC 10A 30VDC 12A 277VAC/250VAC Resistive at 70°C 1/3HP 125VAC at 40°C
		AgSnO2	2 Form A	10A 250VAC 10A 30VDC 12A 277VAC/250VAC Resistive at 70°C 1/3HP 125VAC at 40°C 3/4HP 250VAC at 40°C
			2 Form C	10A 250VAC 10A 30VDC 12A 277VAC/250VAC Resistive at 70°C 1/3HP 125VAC at 40°C 3/4HP 250VAC at 40°C
	W type	AgSnO2	2 Form A	12A 277VAC/250VAC Resistive at 70°C 1/3HP 125VAC at 40°C 3/4HP 250VAC at 40°C
TÜV		AgNi	2 Form A	12A 250VAC
			2 Form C	10A 250VAC
		AgSnO2	2 Form A	12A 250VAC
VDE	W型	AgSnO2	2HT 2ZT	10A 250VAC
CQC		AgSnO2	2HT 2ZT	12A 250VAC
		AgNi	2H3 2Z3	

Notes: 1) All values unspecified are at room temperature.
2)Only typical loads are listed above. Other load specifications can be available upon request.

ORDERING INFORMATION

HF140FF/ 012 -2H S W T G F (XXX)

Type	HF140FF/	
Coil voltage	3, 5, 6, 9, 12, 18, 24, 48, 60VDC	
Contact arrangement	**2H:** 2 Form A	**2Z:** 2 Form C
Construction 1) 2)	**S:** Plastic sealed(No smoky-gray cover)	**Nil:** Flux proofed
Contact Gap	**W:** Large contact gap 3)	**Nil:** Standard
Contact material	**T:** $AgSnO_2$	**3:** AgNi
Contact plating	**G:** Gold plated	**Nil:** No gold plated
Insulation standard	**F:** Class F	**Nil:** Class F
Special code 5)	**XXX:** Customer special requirement	**Nil:** Standard

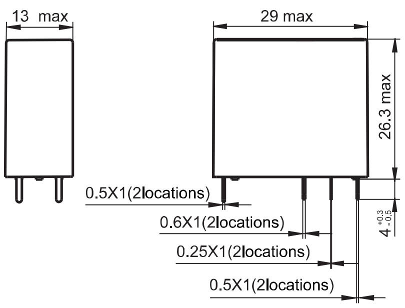
Notes: 1) We recommend flux proofed types for a clean environment (free from contaminations like H2S, SO2, NO2, dust, etc.). We suggest to choose plastic sealed types and validate it in real application for an unclean environment (with contaminations like H2S, SO2, NO2, dust, etc).
2) Contact is recommended for suitable condition and specifications if water cleaning or surface process is involved in assembling relays on PCB.
3) There are two specifications to W type: 1.5mm contact gap and 2.0mm contact gap.The default W type is 1.5mm. So please add the special code "(456)" when releasing order, if 2.0mm contact gap is required.(Only for 2 Form A).
4) The standard type is made of black cover. If smoke cover is required, please add a special suffix when ordering. Please take note that smoky-gray cover is only availabe for flux proofed types.
5) The customer special requirement express as special code after evaluating by Hongfa. e.g.(456) means contact gap can reach 2.0mm.

OUTLINE DIMENSIONS, WIRING DIAGRAM AND PC BOARD LAYOUT

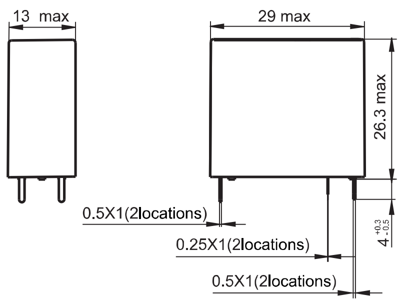
Unit: mm

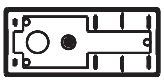
Outline Dimensions

2 Form C

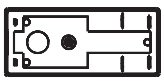


2 Form A





(Bottom view)



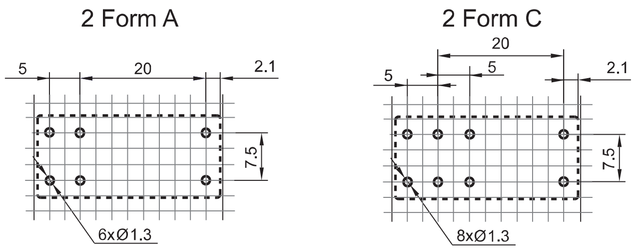
(Bottom view)

OUTLINE DIMENSIONS, WIRING DIAGRAM AND PC BOARD LAYOUT

Unit: mm

Wiring Diagram (Bottom view)

PCB Layout (Bottom view)



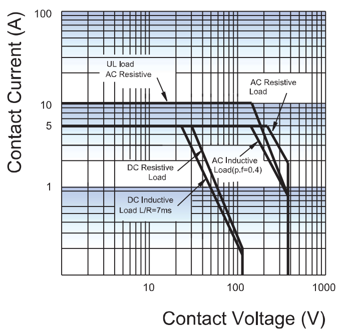
Remark: 1) In case of no tolerance shown in outline dimension: outline dimension ≤1mm, tolerance should be ±0.2mm; outline dimension >1mm and ≤5mm, tolerance should be ±0.3mm; outline dimension >5mm, tolerance should be ±0.4mm.

2) The tolerance without indicating for PCB layout is always ±0.1mm.

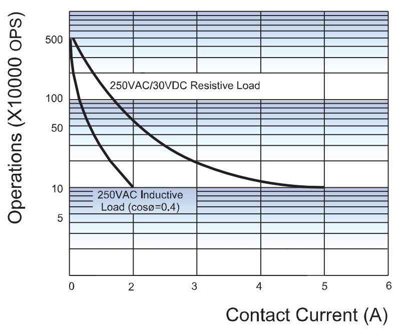
3) The width of the gridding is 2.5mm.

CHARACTERISTIC CURVES

MAXIMUM SWITCHING POWER

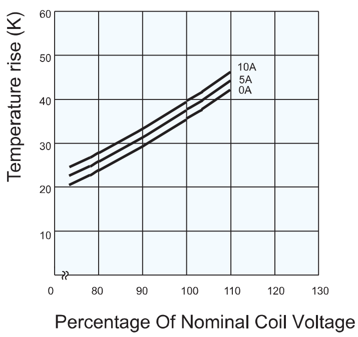


ENDURANCE CURVE



Test conditions:
NO, Resistive load, Flux proofed,
Room temp., 1s on 9s off.

COIL TEMPERATURE RISE



Relay Sockets

File No.: E253370

Features

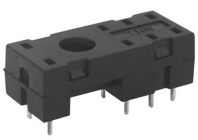
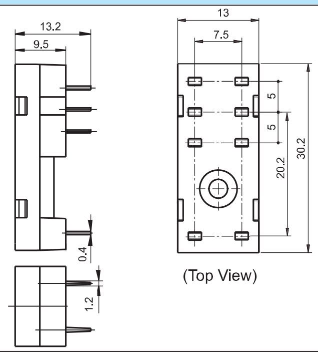
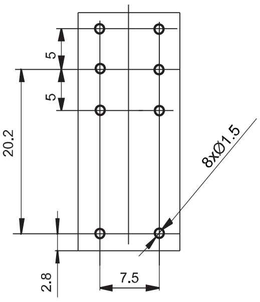
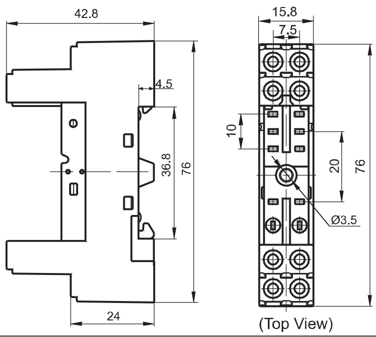
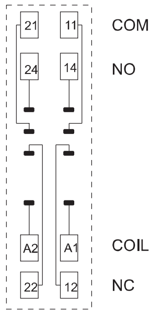
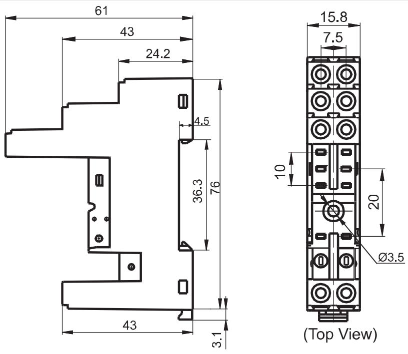
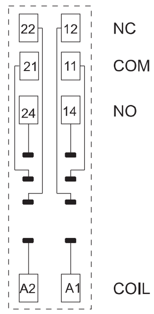
- The insulation resistance is 1000MΩ
- Three mounting types are available: PCB, screw mounting and DIN rail mounting
- With finger protection device
- Many kinds of plug-in modules are available with the function of energizing indication and wiring protection
- Environmental friendly product (RoHS compliant)

CHARACTERISTICS

Type	Nominal Voltage	Nominal Current	Ambient Temperature	Dielectric Strengths.	Screw Torque	Wire Strip Length
14FF-2Z-A1	250VAC	10A	-40 °C to 70°C	5000VAC	—	—
14FF-2Z-C2	250VAC	10A	-40 °C to 70°C	5000VAC	0.6N·m	7mm
14FF-2Z-C3	250VAC	10A	-40 °C to 70°C	5000VAC	0.6N·m	7mm
14FF-2Z-C4	250VAC	10A	-40 °C to 70°C	5000VAC	—	9mm

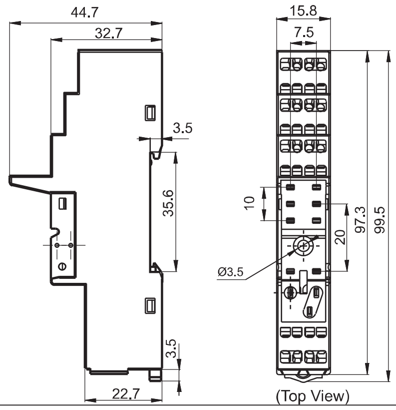
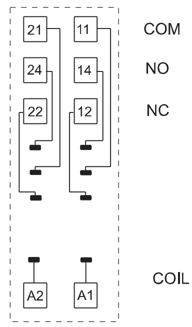
OUTLINE DIMENSIONS, WIRING DIAGRAM AND PC BOARD LAYOUT

Unit: mm

Socket	Outline Dimensions	Wiring Diagram / PCB Layout	Components Available
14FF-2Z-A1  PCB terminal, PCB or Screw mounting	 (Top View)	 (Top View)	metallic retainer 14FF-H3 remarks:the dielectric strength can reach 1500VAC that sockets mounted 14FF-H3
14FF-2Z-C2  Screw terminal DIN rail or Screw mounting With finger protection device	 (Top View)	 (Top View)	plastic retainer 14FF-H6 marker 14FF-M1 plug-in module HFAA to HFHU*
14FF-2Z-C3  Screw terminal DIN rail or Screw mounting With finger protection device	 (Top View)	 (Top View)	plastic retainer 14FF-H6 marker 14FF-M1 plug-in module HFAA to HFHU*

OUTLINE DIMENSIONS, WIRING DIAGRAM AND PC BOARD LAYOUT

Unit: mm

Socket	Outline Dimensions	Wiring Diagram / PCB Layout	Components available
14FF-2Z-C4  Spring-loaded terminal DIN rail mounting With finger protection device	 (Top View)	 (Top View)	plastic retainer 14FF-H6 marker 14FF-M1 plug-in module HFAA to HFHU*

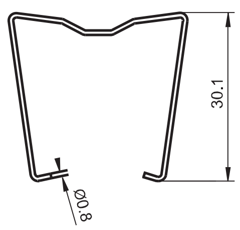
Notes: * Please refer to the product datasheet if plug-in module is required.

DIMENSION OF RELATED COMPONENT (AVAILABLE)

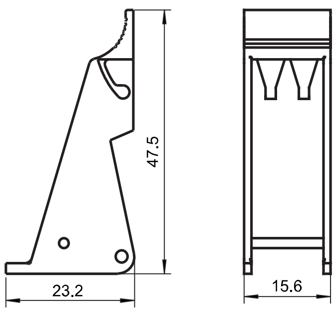
Unit: mm

Retainer

14FF-H3(Metallic retainer)

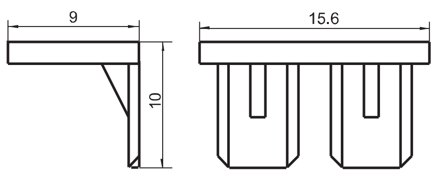


14FF-H6(Plastic retainer)



Marker

14FF-M1



Things to be noticed when selecting sockets:

1. Please choose suitable relay socket according to the actual mounting environment, relay contact poles and terminal layout. If there is any query on selection, please contact Hongfa for the technical service.
2. Socket which can be mounted with markers is furnished with a marker; as for other related components, they should be selected separately. Please do give clear indication of the types of relay sockets and related components you choose while placing order.
3. The above is only an example of typical socket and related component type which is suitable to HF140FF relay. If you have any special requirements, please contact us.
4. Main outline dimension, outline dimension$>$50mm ,tolerance should be $\pm$1mm; 20mm$<$outline dimension $\leqslant$50mm, tolerance should be $\pm$0.5mm; 5mm$<$outline dimension $\leqslant$20mm, tolerance should be $\pm$0.4mm; outline dimension$\leqslant$5mm, tolerance should be $\pm$0.3mm.
5. DIN rail mounting: recommend to use standard rail 35$\times$7.5$\times$1mm, 35$\times$15$\times$1mm.

Disclaimer

The specification is for reference only. See to "Terminology and Guidelines" for more information. Specifications subject to change without notice. We could not evaluate all the performance and all the parameters for every possible application. Thus the user should be in a right position to choose the suitable product for their own application. If there is any query, please contact Hongfa for the technical service. However, it is the user's responsibility to determine which product should be used only.

Current Transducer HX 03..50-P

I_{PN} = 3 .. 50 A

For the electronic measurement of currents: DC, AC, pulsed, mixed, with galvanic isolation between the primary circuit (high power) and the secondary circuit (electronic circuit).

All data are given with R_L = 10 kΩ

Electrical data

Primary nominal current rms I_{PN} (A)	Primary current measuring range I_{PM} (A)	Primary conductor diameter x turns (mm)	Type
3	± 9	0.6d x 20T	**HX 03-P**
5	± 15	0.8d x 12T	**HX 05-P**
10	± 30	1.1d x 6T	**HX 10-P**
15	± 45	1.4d x 4T	**HX 15-P**
20	± 60	1.6d x 3T	**HX 20-P**
25	± 75	1.6d x 2T	**HX 25-P**
50	± 150	1.2 x 6.3 x 1T	**HX 50-P**

V_{OUT}	Output voltage (Anarog) @ ± I_{PN}, R_L = 10 kΩ, T_A = 25 °C	± 4	V
R_{OUT}	Output internal resistance	< 50	Ω
R_L	Load resistance	≥ 10	kΩ
V_C	Supply voltage (± 5 %) [1]	± 15	V
V_C	Current consumption	< ± 15	mA

Accuracy - Dynamic performance data

X	Accuracy @ I_{PN} , T_A = 25°C (xcluding offset)	< ± 1	% of I_{PN}
ε_L	Linearity error (0 .. ± I_{PN})	< ± 1	% of I_{PN}
V_{OE}	Electorical offset voltage @ I_P = 0, T_A = 25°C	< ± 40	mV
V_{OH}	Hysteresis offset voltage @ I_P = 0		
	after an excursion of 1 x I_{PN}	< ± 15	mV
TCV_{OE}	Temperature coefficient of V_{OE}	< ± 1.5	mV/K
TCV_{OUT}	Temerature coefficient of V_{OUT} (% of reading)	± 0.1	%/K
t_r	Response time to 90% of I_{PN} step	≤ 3	µs
BW	Frequency bandwidth (- 3 dB) [2]	50	kHz

General data

T_A	Ambient operating temperature	- 25 .. + 85	°C
T_S	Ambient storage temperature	- 25 .. + 85	°C
m	Mass ...	8	g
	Standards	EN 50178: 1997	

Note: [1] Also operate at ±12V power supplies, measuring range reduced to ± 2.5 x I_{PN}.
[2] Small signal only to avoid excssive heating of the magnetic cores.

Features

- Galvanic isolation between primary and secondary circuit
- Hall effect measuring principle
- Isolation voltage 3000V
- Low power consumption
- Extended measuring range (3 x I_{PN})
- Power supply from ±12V to ±15V
- Isolated plastic case recognized according to UL 94-V0.

Advantages

- Low insertion losses
- Easy to mount with automatic handling system
- Small size and space saving
- Only one design for wide current ratings range
- High immunity to external interference

Applications

- AC variable speed drives
- DC motor drives
- Battery supplied applications
- Uninterruptible Power Supplies (UPS)
- Switched Mode Power Supplies (SMPS)
- Electrical appliances

Application domain

- Industrial

Current Transducer HX 03..50-P

Isolation characteristics

V_d	Rms voltage for AC isolation test, 50 Hz, 1 min	> 3	kV
V_e	Partial discharge extinction voltage rms @ 10 pC	≥ 1	kV
$\hat{V}_w$	Impulse withstand voltage 1.2/50 µs	≥ 6	kV
dCp	Creepage distance	≥ 5.5	mm
dCI	Clearance distance	≥ 5.5	mm
CTI	Comparative Tracking Index (group I)	≥ 600	

Applications examples

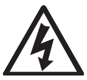
According to EN 50178 and IEC 61010-1 standards and following conditions:

- Over voltage category OV 3
- Pollution degree PD2
- Non-uniform field

	EN 50178	**IEC 61010-1**
dCp, **dCI**, $\hat{V}_w$	Rated insulation voltage	Nominal voltage
Basic insulation	600 V	600 V
Reinforced insulation	300 V	150 V

Safety

This transducer must be used in electric/electronic equipment with respect to applicable standards and safety requirements in accordance with the manufacturer's operating instructions.

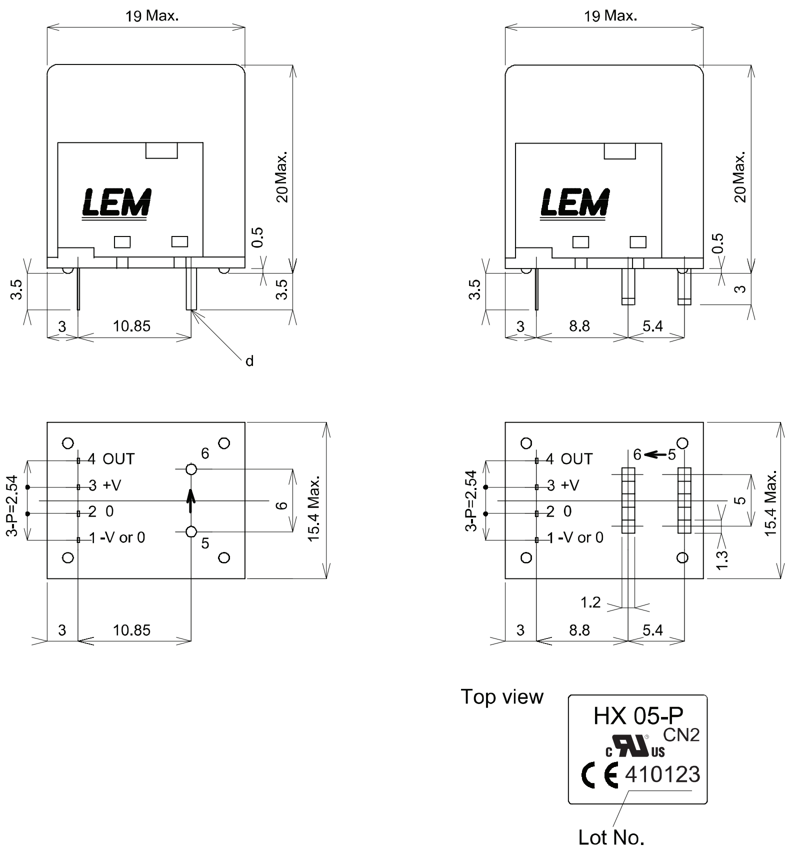


Caution, risk of electrical shock

When operating the transducer, certain parts of the module can carry hazardous voltage (eg. primary busbar, power supply).
Ignoring this warning can lead to injury and/or cause serious damage.
This transducer is a build-in device, whose conducting parts must be inaccessible after installation.
A protective housing or additional shield could be used.
Main supply must be able to be disconnected.

Dimensions HX 03..50-P. (in mm. 1 mm = 0.0394 inch)

HX 03..25-P   HX 50-P



Terminal Pin Identification

1 ..... -15 V
2 ..... 0 V
3 ..... +15 V
4 ..... Output
5 ..... Primary input Current (+)
6 ..... Primary input Current (-)

Primary conductor diameter

HX	03-P	05-P	10-P	15-P
d	0.6	0.8	1.1	1.4
HX	20-P	25-P	50-P	
d	1.6	1.6	1.2 x 6.3	

Secondary pins dimension
0.5 x 0.25

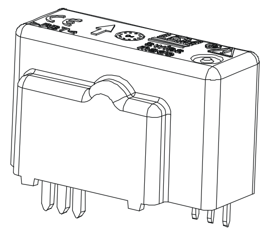
Mechanical characteristics

- General tolerance ± 0.5 mm

Current Transducer LAH 50-P

I_{PN} = 50 A

For the electronic measurement of currents: DC, AC, pulsed ..., with a galvanic isolation between the primary circuit (high power) and the secondary circuit (electronic circuit).



16010

Electrical data

I_{PN}	Primary nominal current rms		50				A
I_{PM}	Primary current, measuring range [1]		0 .. 110				A
R_M	Measuring resistance @		T_A = 70°C		T_A = 85°C		
			$R_{M\,min}$	$R_{M\,max}$	$R_{M\,min}$	$R_{M\,max}$	
	with ± 12 V	@ I_{PN} [± A_{DC}]	0	221	0	214	Ω
		@ I_{PN} [A_{RMS}] [2]	0	115	0	108	Ω
	with ± 15 V	@ I_{PN} [± A_{DC}]	0	335	0	327	Ω
		@ I_{PN} [A_{RMS}] [2]	0	195	0	188	Ω
I_{SN}	Secondary nominal current rms		25				mA
K_N	Conversion ratio		1 : 2000				
V_C	Supply voltage (± 5 %)		± 12 .. 15				V
I_C	Current consumption		10 (@ ± 15V) + I_S				mA

Accuracy - Dynamic performance data

X	Accuracy [3] @ $I_{PN,}$ T_A = 25°C		± 0.25		%
ε_L	Linearity error		< 0.15		%
			Typ	Max	
I_O	Offset current @ T_A = 25°C			± 0.15	mA
I_{OM}	Magnetic offset current @ I_P = 0 and specified R_M, after an overload of 5 x I_{PN}		± 0.10	± 0.15	mA
I_{OT}	Temperature variation of I_O	0°C .. + 70°C	± 0.10	± 0.30	mA
		- 25°C .. + 85°C	± 0.10	± 0.40	mA
t_{ra}	Reaction time @ 10 % of I_{PN}		< 200		ns
t_r	Response time [4] to 90 % of I_{PN} step		< 500		ns
di/dt	di/dt accurately followed		> 200		A/µs
BW	Frequency bandwidth (- 1 dB)		DC .. 200		kHz

General data

T_A	Ambient operating temperature		- 25 .. + 85	°C
T_S	Ambient storage temperature		- 40 .. + 90	°C
R_S	Secondary coil resistance	@ T_A = 70°C	115	Ω
		@ T_A = 85°C	121	Ω
m	Mass		22	g
	Standards		EN 50178: 1997	

Notes: [1] For 10 s, with $R_M \le 71\ \Omega$ (V_C = ± 15 V)
[2] 50 Hz Sinusoidal
[3] Without I_O & I_{OM}
[4] With a di/dt of 100 A/µs.

Features

- Closed loop (compensated) current transducer using the Hall effect
- Printed circuit board mounting
- Insulated plastic case recognized according to UL 94-V0.

Advantages

- Excellent accuracy
- Very good linearity
- Low temperature drift
- Optimized response time
- Wide frequency bandwidth
- No insertion losses
- High immunity to external interference
- Current overload capability.

Applications

- AC variable speed drives and servo motor drives
- Static converters for DC motor drives
- Battery supplied applications
- Uninterruptible Power Supplies (UPS)
- Switched Mode Power Supplies (SMPS)
- Power supplies for welding applications.

Application domain

- Industrial.

Current Transducer LAH 50-P

Isolation characteristics

V_d	Rms voltage for AC isolation test, 50/60 Hz, 1 mn	5	kV
$\hat{V}_w$	Impulse withstand voltage 1.2/50 µs	12	kV
V_e	Partial discharge extinction voltage rms @ 10pC	>2	kV
		Min	
dCp	Creepage distance [5)]	11.75	mm
dCI	Clearance distance [5)]	11.75	mm
CTI	Comparative Tracking Index (Group I)	175	

Application examples

According to EN 50178 and IEC 61010-1 standards and following conditions:

- Over voltage category OV 3
- Pollution degree PD2
- Non-uniform field

	EN 50178	**IEC 61010-1**
dCp, dCI	Rated isolation voltage	Nominal voltage
Single isolation	1000 V	1000 V
Reinforced isolation	500 V	500 V

Note: [5)] On PCB with soldering pattern UTEC93-703.

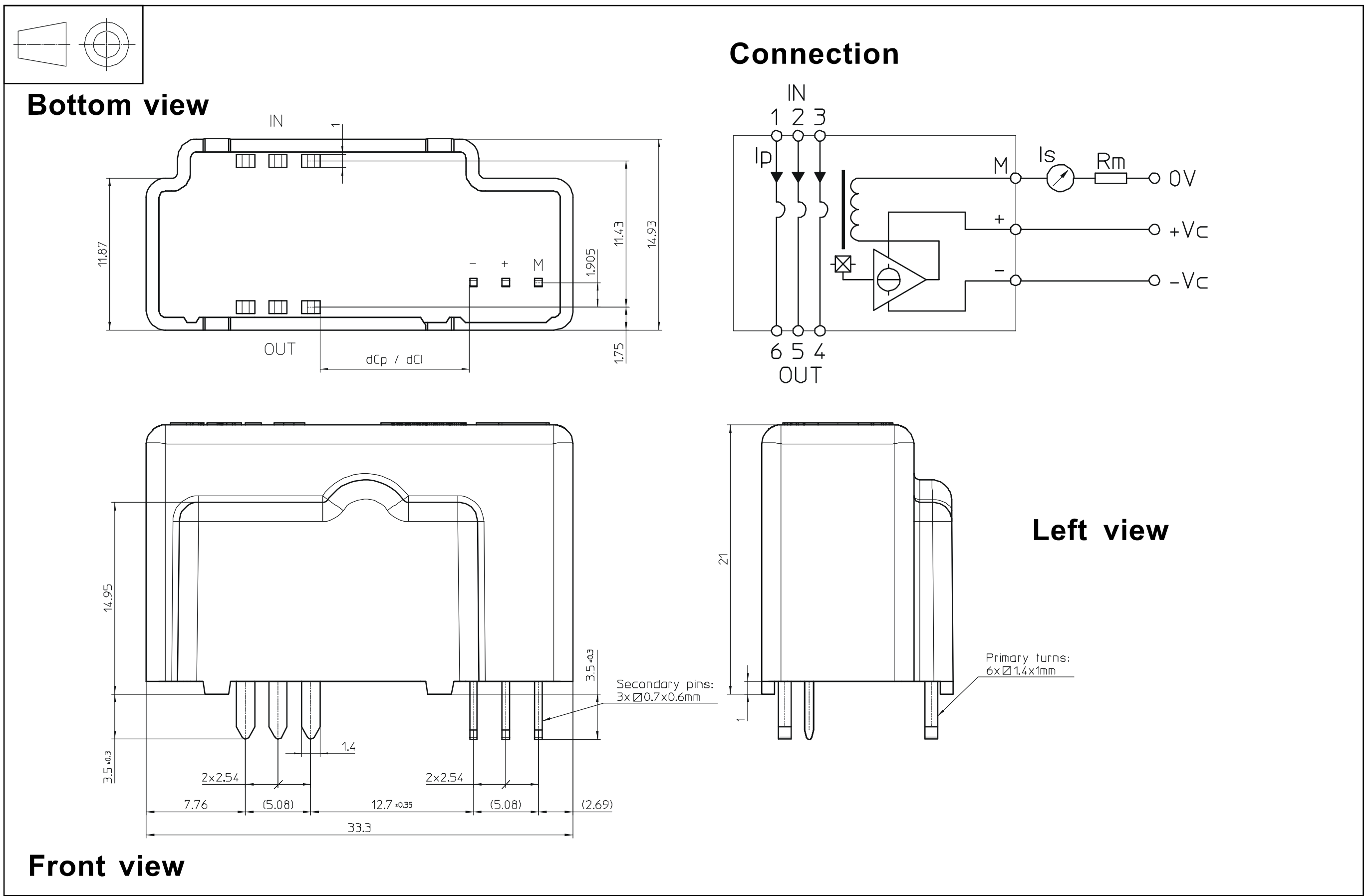
Safety

This transducer must be used in electric/electronic equipment with respect to applicable standards and safety requirements in accordance with the manufacturer's operating instructions.

Caution, risk of electrical shock

When operating the transducer, certain parts of the module can carry hazardous voltage (eg. primary busbar, power supply).
Ignoring this warning can lead to injury and/or cause serious damage.
This transducer is a built-in device, whose conducting parts must be inaccessible after installation.
A protective housing or additional shield could be used.
Main supply must be able to be disconnected.

Dimensions LAH 50-P (in mm. 1 mm = 0.0394 inch)



Number of primary turns	Primary current		Nominal output current	Turns ratio	Primary resistance	Primary insertion inductance
	nominal I_{PN} [A]	maximum I_P [A]	I_{SN} [mA]	K_N	R_P [mΩ]	L_P [µH]
1	50	110	25	1 : 2000	0.12	0.008

Mechanical characteristics

- General tolerance ± 0.2 mm
- Fastening & connection of primary 6 pins 1.4 x 1 mm
  Recommended PCB hole 2 mm
- Fastening & connection of secondary 3 pins 0.7 x 0.6 mm
  Recommended PCB hole 1.2 mm

Remarks

- I_S is positive when I_P flows from terminals "IN" to terminals "OUT".
- The jumper temperature and PCB should not exceed 100°C.
- This is a standard model. For different versions (supply voltages, turns ratios, unidirectional measurements...), please contact us.

XS9C4A2A2P20

inductive sensor XS9 40x40x117 - PBT - Sn25 mm - 12..24VDC - terminals

Download your XS9C4A2A2P20 datasheet

Characteristics | Documents & Downloads

Main

Hide

Range of product	OsiSense XS
Series name	General purpose
Sensor type	Inductive proximity sensor
Device application	-
Sensor name	XS9
Sensor design	Form 40 x 40 x 117
Size	117 mm
Body type	Fixed
Detector flush mounting acceptance	Non flush mountable
Material	Plastic
Enclosure material	PBT
Type of output signal	Analogue
Wiring technique	2-wire
[Sn] nominal sensing distance	25 mm
Output circuit type	DC
Analogue output range	4...20 mA
Electrical connection	Screw-clamp terminals, clamping capacity: 4 x 1.5 mm²
[Us] rated supply voltage	12...24 V DC with reverse polarity protection
IP degree of protection	IP65 conforming to IEC 60529 IP67 conforming to IEC 60529 IP69K conforming to DIN 40050

Complementary

Hide

Detection face	5 positions turret head
Front material	PBT
Operating zone	2...27 mm
Differential travel	3...15% of Sr
Repeat accuracy	<= 3% of Sr
Linearity error	<= 3% of Sr
Cable entry number	1 tapped entry for M20 x 1.5 cable gland
Status LED	1 LED yellow for output state
Supply voltage limits	12...36 V DC
Current consumption	0...4 mA at no-load
Delay first up	<= 7.5 ms
Delay response	<= 6 ms
Delay recovery	<= 6 ms
Marking	CE
Height	40 mm

Length	40 mm
Width	117 mm
Product weight	0.244 kg

Environment

Hide

Product certifications	CCC CSA UL
Ambient air temperature for operation	-25...70 °C
Ambient air temperature for storage	-40...85 °C
Vibration resistance	25 gn amplitude = +/- 2 mm (f = 10...55 Hz) conforming to IEC 60068-2-6
Shock resistance	50 gn for 11 ms conforming to EN 60068-2-27

Offer Sustainability

Hide

Sustainable offer status	Green Premium product
RoHS (date code: YYWW)	Compliant - since 1213 - Schneider Electric declaration of conformity
REACh	Reference not containing SVHC above the threshold
Product environmental profile	Available download Product environmental
Product end of life instructions	Need no specific recycling operations

Contractual warranty

Hide

Period	18 months

THE WORLD OF WEATHER DATA - THE WORLD OF WEATHER DATA - THE WORLD OF WEATHER DATA

Instruction for use

020856/10/07

Wind Transmitter

- with analogue output

4.3303.22.xxx

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www.thiesclima.com info@thiesclima.com

Safety Instructions

- Before operating with or at the device/product, read through the operating instructions.
  This manual contains instructions which should be followed on mounting, start-up, and operation.
  A non-observance might cause:
  - failure of important functions
  - endangerment of persons by electrical or mechanical effect
  - damage to objects
- Mounting, electrical connection and wiring of the device/product must be carried out only by a qualified technician who is familiar with and observes the engineering regulations, provisions and standards applicable in each case.
- Repairs and maintenance may only be carried out by trained staff or **Adolf Thies GmbH & Co. KG**. Only components and spare parts supplied and/or recommended by **Adolf Thies GmbH & Co. KG** should be used for repairs.
- Electrical devices/products must be mounted and wired only in a voltage-free state.
- **Adolf Thies GmbH & Co KG** guarantees proper functioning of the device/products provided that no modifications have been made to the mechanics, electronics or software, and that the following points are observed:
- All information, warnings and instructions for use included in these operating instructions must be taken into account and observed as this is essential to ensure trouble-free operation and a safe condition of the measuring system / device / product.
- The device / product is designed for a specific application as described in these operating instructions.
- The device / product should be operated with the accessories and consumables supplied and/or recommended by **Adolf Thies GmbH & Co KG** .
- Recommendation: As it is possible that each measuring system / device / product may,under certain conditions, and in rare cases, may also output erroneous measuring values, it is recommended using redundant systems with plausibility checks for **security-relevant applications**.

Environment

- As a longstanding manufacturer of sensors Adolf Thies GmbH & Co KG is committed to the objectives of environmental protection and is therefore willing to take back all supplied products governed by the provisions of "*ElektroG*" (German Electrical and Electronic Equipment Act) and to perform environmentally compatible disposal and recycling. We are prepared to take back all Thies products concerned free of charge if returned to Thies by our customers carriage-paid.
- Make sure you retain packaging for storage or transport of products. Should packaging however no longer be required, please arrange for recycling as the packaging materials are designed to be recycled.

Documentation

-
- Although these operating instruction has been drawn up with due care, **Adolf Thies GmbH & Co KG** can accept no liability whatsoever for any technical and typographical errors or omissions in this document that might remain.
- We can accept no liability whatsoever for any losses arising from the information contained in this document.
- Subject to modification in terms of content.
- The device / product should not be passed on without the/these operating instructions.

Contents

1 Models

Order - no.	Measuring range	Electrical output	Model
4.3303.22.040	0...50 m/s	0...20 mA (Load resistor: ≤ 500 Ω)	Standard
4.3303.22.041	0...50 m/s	4...20 mA (Load resistor: ≤ 500 Ω)	Standard
4.3303.22.060	0...50 m/s	0….1 V (Load resistor: ≥ 1000 Ω)	Standard
4.3303.22.061	0...50 m/s	0...10 V (Load resistor: ≥ 1000 Ω)	Standard
4.3303.22.073	0...50 m/s	0…. 5 V (Load resistor: ≥ 1000 Ω)	Standard
4.3303.22.640	0…60 m/s	0...20 mA (Load resistor: ≤ 500 Ω)	Standard
4.3303.22.641	0…60 m/s	4...20 mA (Load resistor: ≤ 500 Ω)	Standard
4.3303.22.660	0…60 m/s	0… 1 V (Load resistor: ≥ 1000 Ω)	Standard
4.3303.22.661	0…60 m/s	0...10 V (Load resistor: ≥ 1000 Ω)	Standard
4.3303.22.673	0…60 m/s	0…. 5 V (Load resistor: ≥ 1000 Ω)	Standard
4.3303.22.841	0…60 m/s	4...20 mA (Load resistor: ≤ 500 Ω)	"Ship version" * - reinforced cup star - special ball bearing

* Wind transmitters for heavy mechanical load, for ex. on ships, wind power plants or the like.

2 Application

The wind transmitter is used for the registration of the horizontal component of the wind velocity. The measuring value will be placed at the output as analogue signal. The signal can be given to display instruments, recording instruments, datalogger as well as process wise systems. The wind transmitter is equipped with an electronically regulated heating system in order to prevent ice and frost from the ball bearings and the outer rotation parts.

Power supply unit, Order no. 9.3388.00.000 provides the transmitter and the heating system with current. It is advisable to attach Lightning rod, Order no. 4.3100.99.000 in areas with considerable lightning activity.

3 Set-up of the instrument

A low-inertia light metallic cup star is set into rotation by the wind. Through the opto-electronic rotating frequency-scanning the resulting pulse frequency is converted through an integrated measuring transducer into an analogue signal. The measuring transducer is normally provided with voltage from the heating system. The instrument can also be used without the heating system. In this case the measuring transducer has to be provided with a separate voltage supply. Input and outputs have to be protected from overload by Transzorb diodes.

The outer parts of the instrument are made of corrosion-resistant anodised aluminium. The sensitive parts inside of the instrument are protected from precipitation through labyrinth seals and o-rings. The instrument is designed to be mounted to a mast, the electrical connection is located in the stem of the transmitter.

It consists of the following parts:

1 Case
1 Cup star
1 Connection plug

4 Recommendation Site Selection / Standard Installation

According to international regulations, the surface wind should be measured at a height of 10 m above flat, open terrain, in order to achieve comparable values. An open terrain is defined as terrain where the distance between the wind-measuring instrument and the next obstacle is at least ten times the height of this obstacle (see VDI 3786, Part 2). If the regulation cannot be adhered to, the measuring instrument should be installed at a height at which the measurement values are not influenced by any local obstacles. In any case, the measuring instruments are to be installed at a height of 6 to 10 m above the mean height of the buildings or trees in the vicinity. If it is necessary to install the instrument on a roof, it should be installed in the centre of the roof in order to avoid any preferential directions.

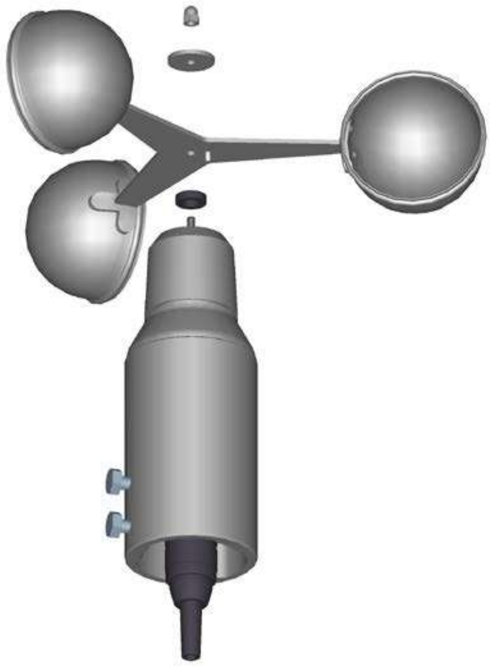
5 Installation

> ***Attention:***
> ***Storing, mounting and operation under weather conditions is permissible only in vertical position, as otherwise water can get into the instrument.***

> ***Remark:***
> *When using fastening adapters (angle, traverses, etc.) please take a possible effect by turbulences into consideration.*

5.1 Mounting of the cup star

Unscrew the cap nut (SW 8) from the wind velocity sensor case and remove the disk. Keep the rubber sealing washer in the protection cap. Set the cup star into position in such a way that the dowel pin in the cup star catches in the nut of the protective cap. Replace the disk and re-screw the cap nut. Hold the transmitter on the protective cap not on the cup.



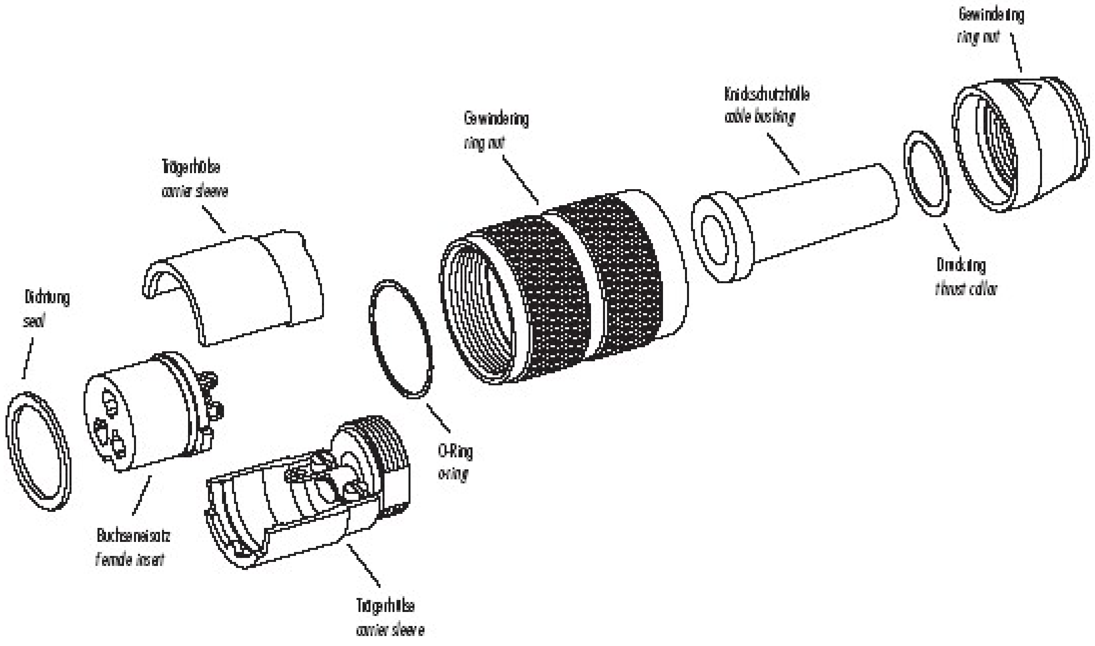
5.2 Electrical Mounting

A shielded cable with a diameter of 5..8 mm and a core section of 0,5…0,75 mm² must be soldered on to the enclosed plug.

- The number of required cores, and the PIN assignment is stated in the connection diagram (chapter 7).

Cable recommendation	
Type/ No. of cores /Diameter	Cable diameter
LIYCY 3 x 0,5 mm² LIYCY 5 x 0,5 mm²	ca. 5 mm ca. 7 mm

Coupling socket 201041 (5-pol), Type Binder, Series 691



1. Removing Coupling socket
2. Stringing coupling socket on cable
3. Stripping cable sheath 20 mm
4. Putting uncovered shield backwards onto the cable sheath
5. Stripping uncovered cable cores 5 mm
6. Pushing shrink hose over cable cores
7. Soldering stripped cable cores onto the solder filament of the bush insert, pushing shrink hose over the soldering afterwards, and shrinking it.
8. Fastening cable and shield in the carrier sleeve by means of the clamp.
9. Mount coupling socket

5.3 Mounting of the Wind Transmitter

Mount the transmitter to a short piece of pipe of R 1½“ (Ø 48 mm) and a length of 50 mm. The short piece of pipe must have an internal diameter of at least 36 mm as the wind transmitter must be connected electrically with a plug from below. Once the electrical connection has been carried out, set the wind transmitter onto the short piece and fasten it to the shaft with the two hexagonal screws.

6 Maintenance

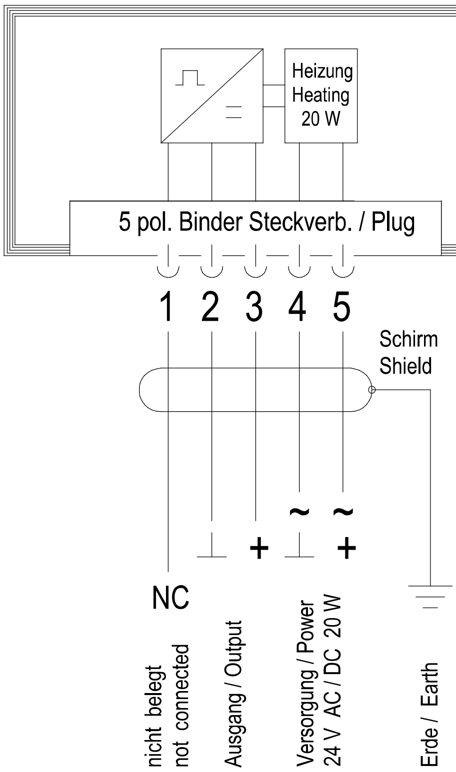
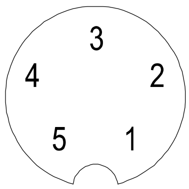
After proper mounting the instrument works maintenance free.

Heavy pollution can clog up the slit between the rotating and the stationary parts of the wind transmitter. This slit must be kept clean.

Remark:
Please use only original packing for transporting the instrument.

7 Connecting Diagram

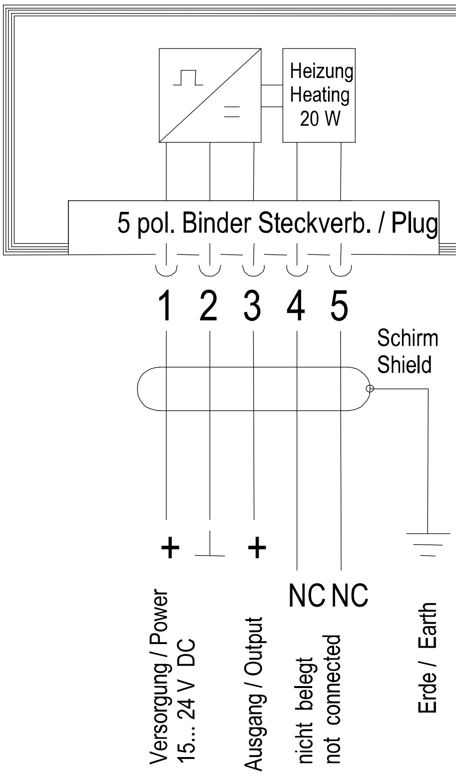
<table>
<tr>
<td>Order - no.

4.3303.22.040
4.3303.22.041
4.3303.22.060
4.3303.22.061
4.3303.22.073
4.3303.22.640
4.3303.22.641
4.3303.22.660
4.3303.22.661
4.3303.22.673
4.3303.22.841</td>
<td>Wind Transmitter: Operation with Heating

</td>
<td>View on the soldered side of the coupling socket

</td>
</tr>
<tr>
<td colspan="3">Attention:
The power ground must be galvanically isolated from the signal ground</td>
</tr>
</table>

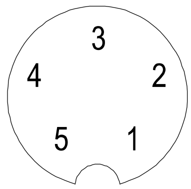
Order - no.

4.3303.22.040
4.3303.22.041
4.3303.22.060
4.3303.22.061
4.3303.22.073
4.3303.22.640
4.3303.22.641
4.3303.22.660
4.3303.22.661
4.3303.22.673
4.3303.22.841

Wind Transmitter: Operation **without** Heating



View on the soldered side of the coupling socket



Attention:
NC: Cable isolating – no connecting

8 Technical Data

Measuring range	see models available
Starting speed	0,3 m/s
Max. load	60 m/s
Electrical output	see models available
Accuracy	± 0,4 m/s resp. 2,5 % of meas. value
Resolution	0,05 m wind run
Wind load at 35 m/s	approx. 10N
Distance constant	5 m
Ambient temperature	-35...+80°C
Operating voltage	
With Heating	24 V AC/DC ca. 20 W; electronically controlled
Without Heating	15 ... 24 V DC
Connecting	5-pole plug
Mounting	onto mast tube 1 ½" , DIN 2441
Weight	1 kg

9 Dimension diagram

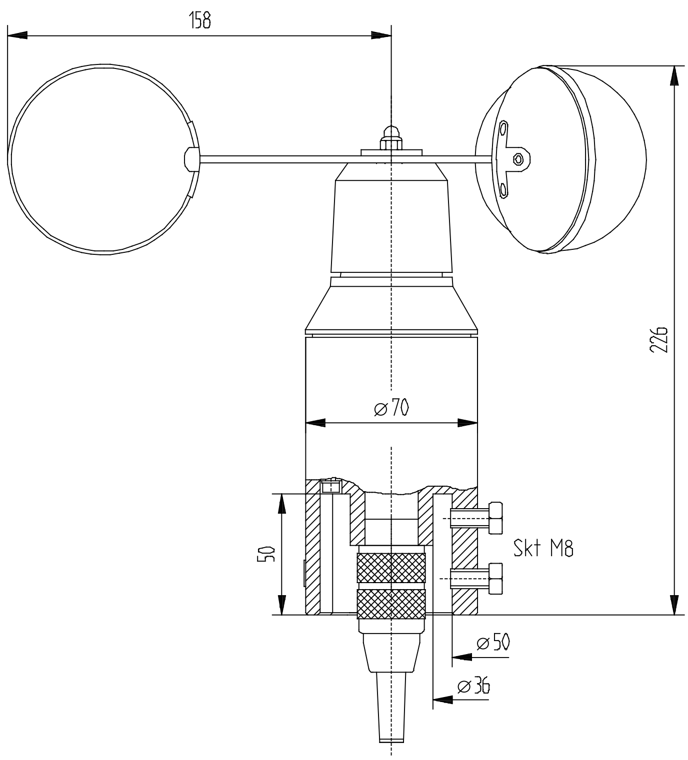


Figure 1: Dimension diagram

10 EC-Declaration of Conformity

Document-No.: **000434** Month: 06 Year: 08

Manufacturer: **A D O L F T H I E S G m b H & C o. K G**
Hauptstr. 76
D-37083 Göttingen
Tel.: (0551) 79001-0
Fax: (0551) 79001-65
email: Info@ThiesClima.com

Description of Product: **Wind Transmitter, Wind Direction Transmitter, Combined Wind Transmitter**

Article No.	**4.3125.32.040**	**4.3125.32.041**	**4.3125.32.060**	**4.3125.32.061**
	4.3125.32.073	**4.3125.32.841**		
	4.3303.22.040	**4.3303.22.041**	**4.3303.22.060**	**4.3303.22.061**
	4.3303.22.073	**4.3303.22.640**	**4.3303.22.641**	**4.3303.22.660**
	4.3303.22.661	**4.3303.22.673**	**4.3303.22.841**	
	4.3324.31.040	**4.3324.31.041**	**4.3324.31.061**	**4.3324.31.073**
	4.3324.31.640	**4.3324.31.641**	**4.3324.31.661**	**4.3324.31.673**
	4.3324.31.941			

specified technical data in the documei **020853/10/07; 020854/11/07; 020848/10/07**

The indicated products correspond to the essential requirement of the following European Directives and Regulations:

2004/108/EC	DIRECTIVE 2004/108/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 15 December 2004 on the approximation of the laws of the Member States relating to electromagnetic compatibility and repealing Directive 89/336/EEC
2006/95/EC	DIRECTIVE 2006/95/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 12 December 2006 on the harmonisation of the laws of Member States relating to electrical equipment designed for use within certain voltage limits
552/2004/EC	Regulation (EC) No 552/2004 of the European Parliament and the Council of 10 March 2004 on the interoperability of the European Air Traffic Management network (the interoperability Regulation)

The indicated products comply with the regulations of the directives. This is proved by the compliance with the following standards:

Reference number	Specification
IEC 61000-6-2: 2005	Electromagnetic compatibility Immunity for industrial environment
IEC 61000-6-3: 2006	Electromagnetic compatibility Emission standard for residential, commercial and light industrial environments
IEC 61010-1: 2001	Safety requirements for electrical equipment for measurement, control and laboratory use. Part 1: General requirements

Place: Göttingen Date: 30.06.2008

Legally binding signature: issuer:

....

Wolfgang Behrens, General Manager Joachim Beinhorn, Development Manager

This declaration certificates the compliance with the mentioned directives, however does not include any warranty of characteristics.
Please pay attention to the security advises of the provided instructions for use.

ADOLF THIES GmbH & Co. KG

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SMALL SENSOR ML-01

Small sensor, great performance

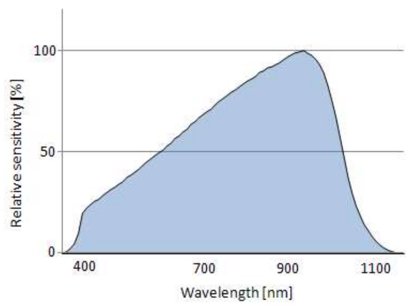
The ML-01 is an industrial grade solar sensor made for PV performance ratio measurements. Due to the compact dimensions of the sensor it can be easily integrated into any application.

NEW !!!

The Si-photodiode sensor ML-01 is the link between reference cells and broadband thermopile pyranometers. Compared to the reference cells it has a proper cosine reponse and it is more compact. Moreover, it also benefits from the same characteristics as a PV module (response time, spectral and temperature response).

Due to its cone shaped diffuser, the ML-01 has a proper response to the incoming radiation at low solar elevation angles. This shape also minimizes soiling effects which could alter the quality of the measurement.

ML-01 is calibrated according to the international calibration method applied to PV reference cells (25°C / AM1.5G / 1000W/m2, AAA Solar Simulator IEC 60904-3 Spectral distribution).



Spectral characteristics

Features

- Same spectral response as a PV module
- Low temperature dependency
- Fast reponse photodiode detector
- Small and lightweight
- Optimized directional response function
- Mounting plate with spirit level

Specifications	ML-01
Spectral response	400 - 1100nm (Mono-Crytalline)
Measuring range	0~2000 W/m2
Output (0~100mV Range)	0~100mV
Response time	<1ms
Operating temperature	-30~+70°C
Temperature dependency (-10~+40°C)	<3%
Directional response (0~80°)	<±5%
Field of View	180°
Non-stability	<2%/year
Output cable	5m for standard version (10m, 30m, or 50m also available)

Specifications are subject to change without further notice