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**Chapter Name: “Design and Development of Sensing Unit for solar”**

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**Abstract:**

 “Highly Sensitive Sensing Unit” for Dual Axis Solar Tracking Systems” has been designed and developed. Under this research work, three types of sensing units have been designed and analyzed. The design of all sensing units is the same except for the pyramid angle. All sensing units have been tested separately.

**1.1 Introduction:**

In the past, photovoltaic solar cell was hooked with fix elevating angle to generate electrical energy. People did not use Tracking system and therefore, low power was generated in the morning to noon and then in afternoon. Maximum power was gained at noon time, when the Sun became perpendicular to the solar cell. Therefore, overall efficiency of electrical power generation was quite low. These day’s dual axis tracking systems are introduced in this field. In this type of system, the solar panel always remains perpendicular to the solar arrays resulting power generation at a higher efficiency. Various types of sensing techniques are used to track the Sun but mostly Light Dependent Resister (LDR) is used as a sensing component. There are many different ways to use LDR. Whereas in previous systems, shadow effect or tubing techniques were used as solar sensors.

“Pyramid type sensing unit” is much more effective and is more efficient as compared to the previous ones, as it can be used in any solar tracking system and is compatible with all types of control circuit.

Pyramid type sensing unit is designed which is more efficient and the sensors can easily be mounted on pyramid. Two pairs of sensors (LDRs) are used. One pair of LDR is for tracking the East-West movement of the Sun (Daily movement) and other pair is for the North-South movement (Seasonal movement). Both LDRs are mounted on the opposite walls of the pyramid. Its sensitivity depends on the pyramid angle θp. When the pyramid angle increases, the sensitivity of the system also increases. A very little displacement of the Sun causes a lot of difference in Sunlight's intensity between the two sensors (one pair). Therefore, the sensitivity increases with the increase in pyramid angle and vice versa. The pyramid angle between 45o to 65o is sufficient for solar photo voltaic panel. In case of High Efficiency Solar Cell, the angle should be in between 60o to 800.

Insulating material like Teflon, Perspex and Bakelite etc. can be used to prepare these sensing units. Because the connection of sensing components goes through it. Therefore, it's material should be an electricity nonconductor. It is found experimentally that this arrangement is best for dual axis trackers. It is very cheap, small in size, highly efficient and easy in manufacturing.

**1.2 Methodology of Sensing Unit:**

# C:\Users\CSIR\Desktop\eeeeeeeee.png

**C**

**B**

**A**

**Figure-1.1: Working methodology of pyramid type sensing unit**

This sensing unit has been built from Circular Rod. The pyramid has been developed at the top end of the rod. Two light dependent resistors (LDR), which are light sensing components, are mounted on the opposite wall face. Suppose these LDR detects the East-West motion of the Sun.

When the Sun moves slightly, the difference in the light intensity of the solar light falling on both the LDRs produces. As the intensity of light falling on the LDR decreases, the resistance of the LDR increases and vice versa. As the intensity decreases on one LDR and at the same time intensity increases on the other LDR. Due to which the difference of resistance between the two LDRs increases. Which in other words can be called the "sensitivity" of the sensing unit. As the pyramid angle increases, the difference in resistance increases. Therefore, we can say that as the pyramid angle increases, the sensitivity of the sensing unit increases.

Assume that the intensity of solar light is I0, the solar light intensity falling on them are named Is1 and Is2respectively.θp is the angle between pyramid base to pyramid wall. Angle Ø is the angle between solar arrays and pyramid wall face at “Zero Position”. When, the light intensity of solar light falling on the both sensing component (LDR) is equal, this position of the tracker is referred to as the "zero position”. If the Sun is moved towards east to west direction by an angle "α", the angle between solar arrays with pyramid wall face will be Ø1 and Ø2 (as shown in Figure-1.1, B)

 At equilibrium position (Zero Position) (Figure-1.1, A):

Is1 = Is2=I0 sinØ

And Ø= (900- θp), where

θp = Pyramid Angle

I0 = Intensity of the Sunlight

# Is1 = I0 sinØ (Effective Light intensity on Sensor 1)

# Is2 = I0sinØ (Effective Light intensity on Sensor 2)

# With the little displacement, angle “α”, of the Sun (Figure-1.1, B) and the difference in intensity will be as follows:

∆I = Is1-Is2

Or ∆I= I0sinØ2– I0sin Ø1

#  ∆I= I0 {sinØ2– sin Ø1},

# Or ∆I = I0 {sin (900- θp + α) – sin (900- θp- α)}

Where Ø1= (900- θp- α) & Ø2= (900- θp + α)

Let us assume α=100 and I0 =500 LUX

 Then ∆I= 500{sin (1000- θp) – sin (800- θp)}

Therefore, a little displacement (α) of the Sun is (Figure-2, B),

 Is2 >Is1 and hence R2 <R1, Where R1and R2 are the resistances of LDR1 and LDR2 respectively.

As these LDRs are connected in series voltage divider branches in the control circuit. Hence, there will also be a difference in voltage across the LDR. If VR1 and VR2 are the voltage across the LDR1 and LDR2 respectively then, for according to the above condition:

 VR2<VR1

Due to the difference in light intensity, the difference in resistance of both LDRs of pair also arises. This difference in resistances causes the unequal input signal to the comparator. The input signal voltage depends on the resistance of the sensor. Signal voltages also change according to the change of resistance of the sensor. The comparator compares these signal voltages and gives output accordingly. This output voltage of the comparator is the input signal voltage of the driving circuit. Driver circuit rotates the tracker in such a way that the resistances of this LDR pair tends to become equal, in other words, the system resumes “Zero Position”.

In this research, different pyramids of different pyramid angles are developed and sensing units formed. The sensitivities of these sensing units are tested at a fixed the Sun displacement angle "α". We found that the sensitivity is increased as we increase the pyramid angle. In solar tracking systems, a sensing unit which have pyramid angle between 45 degrees to 75 degrees can be used. The sensing units which have pyramid angle between 45 degrees to 60 degrees is very useful for tracker for simple silicon based solar cells. But in the tracking systems, which is designed for high efficiency solar cells, the sensing units which have pyramid angle between 60 degrees to 75 degrees is more beneficial to use. Because the Fresnel lens is light and unbreakable, its surface flattens despite being a convex lens. Apart from this, it has many properties, so it is also used in tracking systems to concentrate the solar light. The "high efficiency solar cell" is fixed at the focal point. Concentrated light is more displaced by slight displacement of the Sun. For this, a sensing unit which has pyramid angle of 70 degrees or more is used. Table-1.1 shows the effect of pyramid angle on the perpendicular component of solar light intensity falling on the LDRs (assuming light intensity I0 =500 LUX and α=100).

**Table- 1.1:** Effect of Pyramid Angle on Sensors:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **S. No.** | **Pyramid Angle(θp)** | **Is2 = I0 sinØ2** | **Is1 = I0 sinØ1** | **∆I(Difference in Intensity for α=10 degree)** |
| 1. | 30 | 469.85 | 383.02 | 86.83 |
| 2. | 45 | 409.58 | 286.79 | 122.79 |
| 3. | 55 | 353.55 | 211.31 | 142.24 |
| 4. | 60 | 321.39 | 171.01 | 150.38 |
| 5. | 70 | 250.00 | 86.82 | 163.18 |
| 6 | 80 | 171.01 | 0 | 171.01 |

If we assume the difference of light intensity is sensitivity, we find that as the pyramid angle increases, the sensitivity also increases. Because as the pyramid angle increases, the face slope of the pyramid will increase, due to which if the Sun is moves slightly, it will cause a large difference in the light intensity on both sensors of the pair of the sensing unit. The graph (Figure-1.2) shows the relation between the pyramid angle and the difference of light intensity. As the pyramid angle increases, the difference of indenting light intensity increases. Hence the sensitivity is increases also.

**Figure-1.2: Graph between pyramid angle and difference in intensity**

If the value of the pyramid angle is "Zero", it means the upper end of the circular rod is flat and Pyramid is Imaginary. All faces of pyramid are on the same plane. From this virtual pyramid, light of equal intensity falls on all sensors. If the Sun is displaced from some angle, the equal light intensity will be obtained on all the sensors. Therefore, we will not receive any difference in light intensity by the sensors. As shown in Figure-1.2, if the pyramid angle is at 30 degrees then the actual pyramid emerges on the top of the circular road. In this case, the faces of the pyramids are formed on different plane. Sensors of sensor pairs, which are mounted on opposite faces, will have different intensity of light on both sensors due to the displacement of the Sun. When the sun is displaced from some angle, there is some difference in the intensity of light falling on all the light sensors in the sensing unit. This difference depends on the value of the pyramid angle. However, the difference in intensity will also be less but it is sufficient for tracking systems. Similarly, as the pyramid angles increase, the difference in intensity of solar light falling on both pairs of sensors increases due to the displacement of the Sun. After 70 degrees of pyramid angle, as the pyramid angles increase, the top of pyramid will be sharper. This will increase sensitivity, but many other problems will arise.

**1.3 Design of pyramid type sensing unit:**

To design and develop a device or system, it is very important to have thorough knowledge about all the aspect of the system viz how the device is going to be incorporated effectively in the system. Before designing any device, several aspects related to the needs to be considered. It is important to understand the concept of the device. We need to explore all the fabrication and maintenance aspects also so that the functioning of the developed device will remain smooth. We need to consider all the mechanical and electrical requirements for the system or device. One also has to pay attention. After all, we prepare his imagery model as per our requirement. If software is used for this task, it has many other advantages i.e. all the functions of simulation can be done at the same time and the starting-to-end results of the device can be viewed by the software. Any design can be defined in two ways, first by drawing and second by developing a modal. While preparing the drawing, the engineer carefully considers all aspects of the device so that the problem can be solved through scientific way. Figure-1.3 shows the flow chart regarding methodology of device.

***Methodology***

***Diagram***

**Concept**

**And**

**Ideas**

**Output**

**Requirement**

**Mechanical**

**And**

**Electrical Design**

**Physical Model**

**Modification if Required**

**Testing**

**Output**

**Results**

**Figure-1.3: Block diagram of methodology of Sensing Unit**

Having in mind the features mentioned above, the concepts of "Highly Sensitive Sensing Unit" has been designed by using “Solid Works” software. Before making a mechanical product, it is necessary to prepare a proper drawing of it and try to make it as efficient as possible. "Solid Works" software provides the user with the ability to view various aspects of the product designed and its performance. This software also has the facility of simulation, which can make the best product.

According to the design of the “Sensing Unit”, this unit consists of following parts:

* 1. Pyramid
	2. Sensing Components (LDR)
	3. Mounting L-Plate
	4. Chuck-Nut
	5. Printed Circuit Board
	6. 5-Pin Connector
	7. Top Cover
	8. O-ring
	9. Bottom Cover (Cap)
	10. Metal Screws
	11. Gland (5 mm)

The main part of this sensing unit is a pyramid type base. All the sensors are mounted on the face of pyramid. We can use a square, rectangular or cylindrical insulator material rod to fabricate the pyramid. The pyramid base made up of these has its own distinct characteristics. If the pyramid is fabricated on the square rod, then the shape of the pyramid face is obtained in the shape of an "Isosceles triangle". Because of this the edge formed at the bottom side of the pyramid face become in a straight line and so due to this the light which is supposed to be fall on the sensing unit will be scattered due to edge effect. Because of this the sensitivity of the sensor will be affected. In addition to this many more other problems were also faced during fabrication of the top cover. Besides that, there will also be problem with the sealing in this kind of design. In case of the circular rod, the bottom surface of the pyramid formed will be a curved surface instead of a straight line. Because of this the scattering issues will be sorted out. It also has its own distinct advantage. All the four faces in this design will meet at a common single point on upper side of the pyramid.

In this sensing unit, the pyramid, on which the sensing components are mounted, is an important part. Three different types of sensing units have been designed and developed in this research work. These differ from each other by their pyramidal angles. To make this, a material is used which is a bad conductor of electricity and can be easily machined. This material should also be such that temperature does not have any adverse effect on it. Therefore, we can use Teflon / Nylon / Bakelite materials to develop them. Here, black Nylon rod has been used to develop different types of sensing unit. Nylon is also an electrical nonconductor material and it can be easily machined. The advantage of black color is that the light will not be reflected which will not have any adverse effect on the sensitivity of the unit.

The diameter of the rod is 23 millimeters. Pyramid is developed on the top of the rod. The pyramid angles are 450, 600 and 700 respectively. A circular and half round groove is made below the pyramid surface to fix the round O-ring. This O-ring hold the top cover and provides the sealing of top glass cover also. Below 2 mm of the groove, a step of 23 mm diameter and 2 mm thick is made to hold the sensing unit with holding L-plate. After the step, up to 10 mm in length, M18 threads have been made for the chuck-nut. On the four surface of the pyramid 8-holes of 1 mm diameter, 14-PCD (two holes on each wall surface) are made so that single sensing component can be mounted. A press-fit arrangement has been installed in each hole that holds the sensing component. Sensing component connects through this press-fit arrangement to the PCB, which is fixed at the bottom of the pyramid.

Different type of systems and machineries has been used to fabricate the base of pyramid. We also need to know about the systems used. In this work, firstly, the lathe machine is used. To fabricate the cylindrical shape of the sensing unit, the lathe machine has been used. Centre Lathe has been used here for the development of the different parts of the sensing unit. For example, Pyramid body, Chuck-nut etc. “Milling machines have been used after the use of the lathe machine. Metal removing processes done by using Milling Machine. Circular multipoint cutter, which is fixed in rotatable horizontal shaft, is the main cutting tool. Due to the multipoint cutting edges, the metal removing rate is higher in this machine. This machine is also used in surface finishing with high accuracy. There is another Milling (Vertical), which has been used to make hole on the face of the pyramidal faces as per required PCD.

An L-Plate is designed in such a way that it can hold the pyramid properly. A hole of 19 mm diameter has been made on the plane surface of the L-Plate where the pyramid has been fixed through chuck-nut. L-side of plate is coupled with the solar panel by using metal scews.To protect this plate from corrosion, it is made by stainless steel.Through this L-plate, the sensing unit can be connected to any solar tracking system.

Chuck-nut is required to tighten the sensing unit on the L-plate. The material of Chuck-Nut is also the same, the material from which the pyramid is built.This chuck-nut is tighten on the bottom side of the pyramid, hence, the threads are made in the chuck-nut are same as per the threadsof pyramid bottom.

A printed circuit board (PCB) have been provided and fixed it on the bottom end. All the sensing components have been connected with it through press-fit arrengement. A 5-pin male connector have been also proveded on the PCB. All the connections of the sensing components have been made with it. This connector makes it easy to connect the control cable of the control unit. This PCB has been designed by Proteus Software.

This sensing unit is fitted with a solar panel installed in the solar tracking system, Which is installed in an open environment outside.All environmental conditions have to be endure like rain, cold, heat and storm.To protect the sensing components from the adverse conditions of the environment, a glass cap has been installed on the top of the pyramid. The DOME shaped and circular cap have been made from Borosil glass. It is fixed above the pyramid by the O-ring which is provided in the pyramid.

Similarly, to protect the sensing unit from adverse environmental conditions an another cap has been provided at bottom side of pyramid also.This cap can also be opaque. We have made it from the same material as the pyramid has been made.On one side of this cap, threads are made accordingly, so that it can be tightened after chuck-nut at the bottom of the pyramid.A hole has been made at the bottom of this cap, in which gland has been installed. The control cable is passed through this gland.

**1.4 Description of sensing unit:**

All the elements of the sensing unit has been displayed. Pyramid (1) is mounted on the Stainless Steel L-plate (3) with the help of a chuck-nut (4). All the sensors (2) are mounted in sequential manner on the pyramid walls and end connections of the sensors pin are connected to the press-fit arrangement which are already connected with the PCB (5). This PCB (5) is screwed (12) at the bottom of the pyramid. 5-pin connector (6) is mounted on PCB and connected to all the sensors. The main control circuitry takes signals of sensors by a five core cable (0.5 mm) through the 5-pin connector passing through gland hole (11). A transparent glass cap (7) is fitted on the top of the pyramid with the help of Neoprene O-Ring (8), in order to prevent it from harsh weather conditions. There is one more cap (9) having internal threads is tightened with the bottom of the pyramid. L-type SS plate (3) is screwed (9) with the main solar panel. This assembly can be fitted on either sides say east side or north side on the solar panel.



**Figure-1.4: Schematic diagram of sensing unit**

**Conclusion:**

An in-depth study has been carried out about the earlier research work related to the design and development of sensing units before the development of our “Highly Sensitive, Multipurpose Pyramid Type Sensing Unit”. What was uniqueness in the earlier designs and what flaws we saw in them, were also taken into consideration. Although the design of all investors was good, but behind every good there is some evil. Due to which the sensitivity of the sensing unit is affected. In the new design, we have included all the goodness of those sensing units and reduced the deficiencies of that unit in our design. For this, some changes have also been made in the design. Changes have also been made in the material of the sensing unit. The sensing unit is designed in such a way that the user does not face any type of problem from fabrication to installation and maintenance.

This sensing unit can also be used to automatically turn OFF /ON the light (street light, Porch light and garden light etc.) in the day/night respectively.

This sensing unit can be used in other interesting applications such as fire extinguishing by using robotic arms. At present, fire extinguishing work is done by humans, which is very risky. There is also life risk in this work. Technically the robotic arm is a good choice which can replace the role of human from the fire extinguishing. The robotic arm can be made more movable and automatic by using the sensing unit. The sensing unit would be coupled with the robotic arm which senses the fire according to the illumination. The sensing unit will give the signal to the driving unit of the robotic arm which rotates the arm in such a way that the water spray will be on the fire of higher illumination. The sensing unit based robotic arm would be very useful and safe for the human life also. The robotic arm can reach very nearer to the dangerous fire than the human.