# Design and Analysis of Spiral Path Single Actuator Solar Tracking System to Maximize Solar Panel Output

**Abhishek Nandkishore Kode[1], Sagar Vishnurao Wankhede[2]**

[1]*PG Student, Department of Mechanical Engineering, Sinhgad Institute of Technology Lonavala, abhishekkode@gmail.com*
[2]*Assistant Professor, Department of Mechanical Engineering, Sinhgad Institute of Technology Lonavala, svw8890@gmail.com*

## ABSTRACT

***Economic development of any country is based on the Energy. In today's world Electricity plays a critical role in day to day life. A primary conventional energy resource like fossil fuels to Electrical power has been used exhaustively. So there is need to explore the alternative resource to conventional primary resources to fulfil the increasing demand of Electricity. Solar energy is the everlasting and green resource to generate electricity. Conversion of the Solar Energy to Electricity is carried out by the help of photovoltaic panels.***

***One of the Efficiency deciding factors of These PV panels is mounting. Efficiency of these PV is low in fixed type system as compared to various tracking system. Generally in single axis system panel is moved in east to west direction. The Efficiency of any system is directly depends upon the direction of sun rays .i.e. for optimum output sunrays should be exactly normal to PV panel. Similarly in dual axis systems having two drives for motion in two axes. To maintain the angle of the tilt of the solar panel according to the solar direction is the most difficult and demanding task. Currently available trackers in market are bulky, costly hence less effective.***

***The proposed spiral path single actuator solar tracking ensures fast and effective tracking in least possible space and cost , more over system being portable can also be used in mobile applications also.***

***The design development and analysis of the above said system using is carried out. Also the testing mechanism is also proposed for to performance evaluation of the system and its effectiveness over the existing system.***

***Keywords:** Solar Tracker, Solar Panel, Sun Tracker.*

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## 1. INTRODUCTION

Economic development of any country is based on the Energy. In today's world Electricity plays a critical role in day to day life. A primary conventional energy resource like fossil fuels to Electrical power has been used exhaustively. So there is need to explore the alternative resource to conventional primary resources to fulfil the increasing demand of Electricity. Solar energy is the everlasting and green resource to generate electricity. Conversion of the Solar Energy to Electricity is carried out by the help of photovoltaic panels.

Electricity is being derived from primary-conventional energy sources like fissile fuels which are dangerous to environment as well as most likely to deplete in near future. World oil and gas reserves are estimated at just 45 years and 65 years respectively. Coal is likely to last a little over 200 years.

How to fulfil such huge consumption in future?

Only one most beneficial option is Renewable energy. Renewable energy is energy obtained from sources that are essentially inexhaustible. Examples of renewable resources include wind power, solar power, geothermal energy, tidal power and hydroelectric power. The most important feature of renewable energy is that it can be harnessed without the release of harmful pollutants. Renewable energy is generally defined as energy that is collected from resources which are naturally replenished on a human timescale, such as sunlight, wind, rain, tides, waves, and geothermal heat [7].

Solar Energy is having huge advantages compare to other renewable. Solar energy is a clean, renewable resource that is continuously supplied to the earth by the sun. Solar resources are available everywhere in the world. It gives out no emissions i.e. environmentally safe, Energy security to the country, No dependency on foreign resources for electricity generation, Can be permitted and installed faster than other traditional or renewable power plants, Produces local, on-site energy, which reduces the need for extensive high-voltage transmission lines or a complex infrastructure. Reliable over the long term, with no moving parts, fixed photovoltaic systems last longer than other energy sources, clean, quiet and visually unobtrusive in nature. Solar energy plants do not have any polluting emissions, do not make any sound, and are not considered to be an "eyesore"[8].

Solar Energy Applications are divided in to Thermal Applications and Photovoltaic applications. In India Solar PV applications include solar home systems, solar power plants, solar lighting (street lighting, home lighting systems and lanterns), solar pumping, PV modules for telecommunications and data logging. PV applications are not constrained by the availability of sites or roof area. However the efficiency is a most important barrier.

### 1.1 Background

To get the most from solar panels, you need to point them in the direction that captures the most sun. But there are a number of variables in figuring out the best direction. This advice applies to any type of panel that gets energy from the sun; photovoltaic, solar hot water, etc. We assume that the panel is fixed, or has a tilt that can be adjusted seasonally. (Panels that track the movement of the sun throughout the day can receive 10% (in winter) to 40% (in summer) more energy than fixed panels.

Solar panels should always face true south if you are in the northern hemisphere, or true north if you are in the southern hemisphere. True north is not the same as magnetic north. If you are using a compass to orient your panels, you need to correct for the difference, which varies from place to place.

The graph below shows the effect of adjusting the tilt. The turquoise line shows the amount of solar energy you would get each day if the panel is fixed at the full year angle. The red line shows how much you would get by adjusting the tilt four times a year as described below. For comparison, the green line shows the energy you would get from two-axis tracking, which always points the panel directly at the sun. These figures are calculated for 40° latitude.

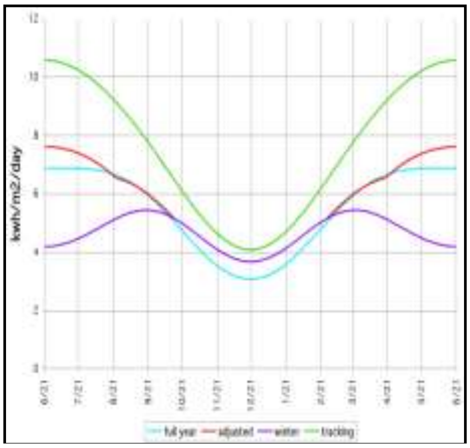



**Fig-1: Effect of adjusting the tilt**

Again there are more positions in the year at which the tilt should be change according to the solar and winter angle. Two times or four times tilt can give better efficiency. But again question arise that how should one calculate the angle and time of the tilt in the year to get better efficiency fro solar PV panel.

### 1.2 The Present Solutions

There are actually several solutions for two axis solar tracking systems using electromechanical devices, in which a controller detects the Sun apparent position, and controls the position of the structure supporting the panels toward the sun by enabling the engines movement. These devices are based upon the solar maps. These devices are costly & bulky.

So there is need to develop the simple and cheaper device that can helped to get maximum output from PV Panels.

## 2. USEFUL METHODOLOGIES FOR PROPOSED WORK

During growth, sunflowers tilt during the day to face the sun. As the season lapses the movement is also changes with the sun direction irrespective of the magnetic directions. The whole movement is the combination of the two axes. Two axes tacking in winter & summer season is implemented in the work.

The trajectory decided to develop a mechanism is spiral which is analogous to sunflower movement across the season.

Second analogy to design the solar tracker is principal of the high speed spiral scanner used in the RADAR application.

## 3. DESIGN

When the motor shaft rotates the carrier rotates moving the gear in the threaded ring, thus the cam will rotate and there by the angle of the solar panel mounting plate changes in a spiral path dorm 0 to 30 degree (azimuth angles range within 0 to 18 degree for maximum solar panel power) which is necessary to place the job in shortest path as shown in figure above.

### 3.1 Construction and Working

a. NOTE: Main axle (B) is designed to
b. Revolve at a speed of 60 rpm

c. Move lower end of axle(J) outward from its vertical or zero position towards the widest cone angle scanning position and return to zero position once every 40 revolutions of drive axle (B).
d. Carrier (A) is integral with drive axle (B) and is balanced.
e. Helical gear(C), having forty teeth rotates on a pivot integral with the carrier and meshes with the internal worm thread (D) in housing (E).
f. Cam (F) is fixed to gear (C) and revolves with it.
g. Spherical section (G), having its centre at (H), and axle (J) are attached to adapter (K). Since spherical section rests on three equally spaced balls (L), it can easily be given the tilting or conic motion required.
h. The adapter, spherical section, and axle (J) are prevented from revolving with carrier (A) by the projection (M) which engages a slot in housing (E).
i. In operation the gear(C) and Cam (F) move as a unit with the carrier rotating at a high speed with the drive axle (B) so that axle (J), spherical section (G) and adapter (K) perform the required conic motion. At the same time worm thread (D) causes the gear(C) to revolve around its own axis, while the centrifugal force presses the slider (P) against the cam (F).
j. Since the gear and cam are also revolving around the gear axis, the opening angle of the cone varies continuously as dictated by the shape of the cam, thus producing the require spiral scanning motion.
k. When slider reaches the centre flat spring (Q) thrusts it against cam (F), replacing the centrifugal force and new scanning cycle begins.

**PART LIST**

**A. CARRIER**
**B. MAIN AXLE**
**C. HELICAL GEAR**
**D. WORM THREAD**
**E. HOUSING**
**F. CAM**
**G. SPHERE**
**H. PIVOT POINT**
**I. SPHERE SEAT**
**J. AXLE**
**K. SCANNER**
**L. BALL BEARING**
**M. PROJECTION**
**N. SPRING**
**O. OPENING ANGLE**
**P. SLIDER**
**Q. FLAT SPRING**

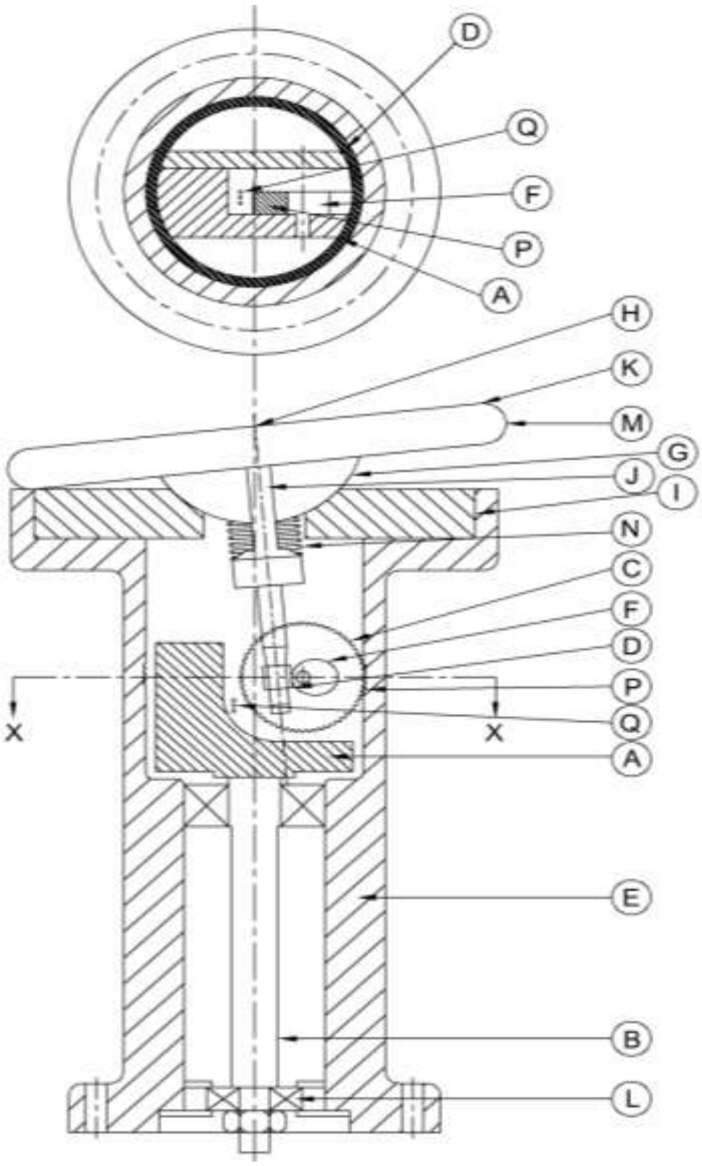



**Fig-2: Construction and Working of Spiral Path Sun Tracker [ 9 ]**

## 3.2 Part Design of Critical Components

**a. Swivel motor**

The drive motor is 12V DC motor coupled to a planetary gear box.
Specifications of motor are as follows:

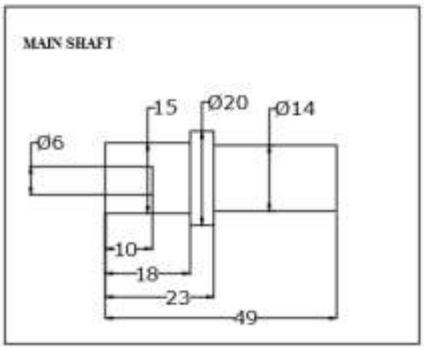
A) Power 5 watt
B) Speed = 150 rpm
C) TORQUE = 0.32 N-m

Drive has a pinion & gear arrangement
Maximum torque = 0.32 N-m
No of teeth on gear =60
No of teeth o pinion = 24
Module = 1.25 mm
Radius of gear by geometry = 60*1.25/2 = 37.5mm
Maximum load = T/r = 0.32 x $10^3$ /37.5 =8.54 N
b = 10 m
Material of spur gear and pinion = Nylon 6
Sut pinion = Sut gear = 60N/$mm^2$
Service factor (Cs) = 1.5
The gear and pinion arrangement where as pinion has 24 teeth and gear has 60 teeth share the entire tooth load…
⇒Pt = (W x Cs) = 12.81 N.
Peff = 12.81N (as Cv =1 due to low speed of operation)
Peff = 12.8 N --------(A)
Lewis Strength equation
WT = Sbym
Where;
Y= 0.484 – (2.86/Z )
⇒ Yp = 0.484 - (2.86/24) = 0.365
⇒ Syp = 21.9
As ⇒ pinion is weaker
$W_T$ = (Syp ) x b x m
=21.9 x 10m x m
$W_T$ = 219$m^2$---------- (B)
Equation (A) & (B)
219 $m^2$ = 12.8
⇒m=0.25 mm
Selecting standard module = 1.25 mm
----for ease of construction as we go for single stage gear box, making size compact, achieving maximum strength and proper mesh.

**b. Design of Main Shaft**

| Material | ULTIMATE TENSILE STRENGTH N/mm2 | YIELD STRENGTH N/mm2 |
|---|---|---|
| EN 24 | 800 | 680 |
| | | |

ASME Code for Design of Shaft.
Since the loads on most shafts in connected machinery are not constant, it is necessary to make proper allowance for the harmful effects of load fluctuations
According to ASME code permissible values of shear stress may be calculated from various relations.
τ = 0.18 Sut = 0.18 x 800 = 144 N/mm2
OR
τ = 0.3 Syt = 0.3 x 680 =204 N/mm
Considering minimum of the above values;
⇒ $\tau_{all}$ = 144 N/mm2
Shaft is provided with dimples for locking; this will reduce its strength. Hence reducing above value of allowable stress by 25%
⇒ $\tau_{all}$ = 108 N/mm2
This is the allowable value of shear stress that can be induced in the shaft material for safe operation.
Torque at motor shaft = 0.32 n-m
Reduction ratio of gear and pinion is 2.5



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$\Rightarrow$ T d = 0.32 x 2.5 = 0.8 N-m

Check for torsional shear failure of shaft.

**Fig-3: Main Shaft**

But as per manufacturing considerations we have an H6h7 fit between the carrier and shaft and to achieve this tolerance boring operation is to be done and minimum boring possible on the machine available is 14mm hence consider the minimum section on the shaft to be 14mm .Assuming minimum section diameter on input shaft = 14mm

$\Rightarrow$ d = 14 mm

Td = $\pi/16 \times \tau \times d^3$

$\Rightarrow \tau = (16 \times Td) / (\pi \times d^3)$

$= (16 \times 0.8 \times 10^3) / (\pi \times (14)^3)$

$\Rightarrow fs_{act} = 1.48$ N/mm$^2$

As $\tau < \tau_{all}$

$\Rightarrow$Main shaft is safe under tensional load

**c. Design of Carrier Hub**

Carrier hub can be considered to be a hollow shaft subjected to torsional load.

Material selection:

| Designation | Ultimate Tensile strength N/mm$^2$ | Yield strength N/mm$^2$ |
|---|---|---|
| AL | 380 | 260 |

As Per ASME Code; (Factor of Safety=3)

$\Rightarrow \tau = 126.67$ N/mm$^2$

Check for torsional shear failure:-

T= $\pi/16 \times \tau \times (Do^4 - Di^4) / Do$

$0.8 \times 10^3 = \pi/16 \times \tau \times (32^4 - 14^4)/322$

$\Rightarrow \tau = 0.129$ N/mm$^2$

As; $\tau < \tau_{all}$

$\Rightarrow$ Hub is safe under torsional load

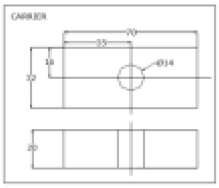

**Fig-4: Carrier Hub**

**d. Design (Selection of Worm Shaft Ball Brg 6002)**

Ball bearing selection.

Series 60

| ISI NO | Brg Basic Design No (SKF) | d | D1 | D | D2 | B | Basic capacity | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | C kgf | Co Kgf |
| 15A C02 | 6002 | 15 | 17 | 32 | 30 | 9 | 2550 | 4400 |
| | | | | | | | | |

## e. Design of Gear Indexer (Cam) Mechanism and Internal Threaded Ring

Maximum torque = 0.8 N-m

No of teeth on gear =30

Module = 2 mm

Radius of gear by geometry = 30 x2 /2 = 30 mm

Maximum load = T/r = $0.8 \times 10^3/30$ =26.7 N

b = 10 m

Material of spur gear and pinion = Nylon 6

Sult pinion = Sult gear = 60N/mm$^2$

Service factor (Cs) = 1.5

The gear and pinion arrangement where as pinion has 24 teeth and gear has 60 teeth share the entire tooth load…

$\Rightarrow$Pt =( W x Cs) = 40 N.

Peff = 40N (as Cv =1 due to low speed of operation)

Peff = 40 N --------(A)

Lewis Strength equation

WT = Sbym

Where ;

Y= 0.484 – 2.86/Z

$\Rightarrow$ yp = 0.484 - 2..86/30 = 0.388

$\Rightarrow$ Syp = 21.923.28

As $\Rightarrow$ pinion is weaker

$W_T$ = (Syp ) x b x m
=23.3x 10m x m
$W_T$= 233$m^2$----------(B)
Equation (A) & (B)
233 $m^2$ = 40
⇒m=0.1716 mm
Selecting standard module = 2 mm ----for ease of construction so that there is proper mesh between the internal threads of the ring and the spur gear.

**f. Design of Tilt Shaft**
Material Selection

| Material | ULTIMATE TENSILE STRENGTH N/$mm^2$ | YIELD STRENGTH N/$mm^2$ |
|---|---|---|
| **EN 24** | 800 | 680 |
| | | |

ASME Code For Design Of Shaft.
According to ASME code permissible values of shear stress may be calculated from various relations.
$\tau$ = 0.18 Sut = 0.18 x 800 = 144 N/$mm^2$
OR
$\tau$ = 0.3 Syt =0.3 x 680 =204 N/mm
Considering minimum of the above values ;
⇒ $\tau_{all}$ = 144 N/$mm^2$
Torque at motor shaft = 0.8 N-m
⇒ T = 0.8 N-m
Check for Torsional Shear Failure of Shaft.
Assuming minimum section diameter on input shaft = 6mm
⇒ d = 6mm
Td = Π/16 x $\tau$ fs $_{act}$ x $d^3$
⇒ $\tau_{act}$ = 16/$\pi$ x Td/ $d^3$
= 16/ $\pi$ x 0.8 x $10^3$ / $(6)^3$
⇒ $\tau_{act}$ = 18.86 N/$mm^2$
As $\tau_{act}$ < $\tau_{all}$ ⇒ Thus, tilt shaft is safe under torsional load

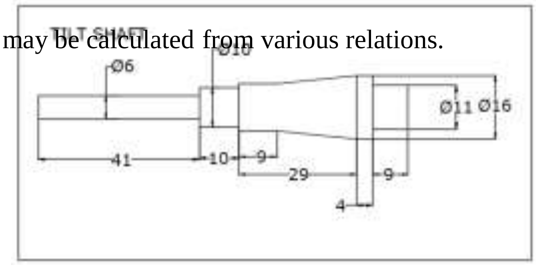

**Fig-5: Tilt Shaft**

### 3.3 Analysis of the Critical Components

FEA is done for the critical components in the system and the results are as follow...

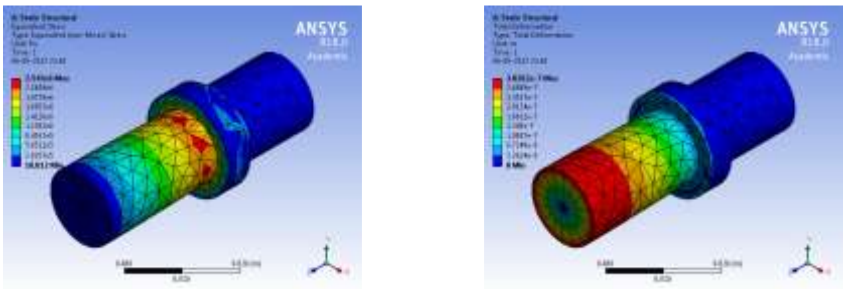

**Fig-6: Analysis of Main Shaft**

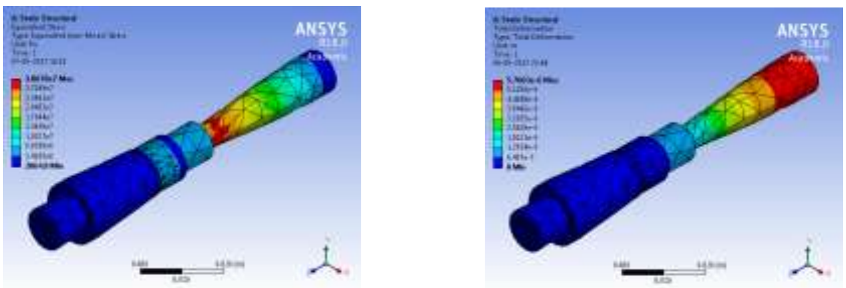

**Fig-7: Analysis of Tilt Shaft**

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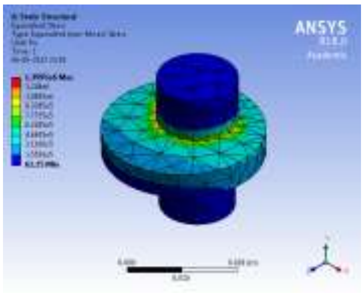

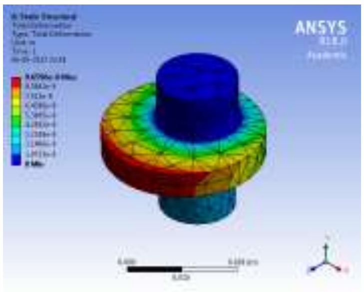


**Fig-8: Analysis of CAM**

## 4. RESULTS AND DISCUSSION

Most of the critical components are designed and FEA is also carried out. So, during design and analysis of critical components of proposed Spiral Path Single Actuator Solar Tracking System to Maximize Solar Panel Output, results are...

| Part Name | Maximum Theoretical Stress N/mm² | Von-misses Stress N/mm² | Maximum Deformation (m) | Results |
|---|---|---|---|---|
| Main Shaft | 1.48 | 2.50 | 3.02 E-7 | Safe |
| Carrier Hub | 0.129 | 0.8 | 1.15 E-8 | Safe |
| CAM | 60 | 1.3 | 8.30 E-8 | Safe |
| Tilt Shaft | 18.86 | 30.6 | 5.70 E-6 | Safe |

**Table-2: Results**

## 5. CONCLUSION

The proposed arrangement spiral path single actuator solar tracker for better output is designed. FEA is done for all critical components and found safe results. The proposed system will give better results that the system available in the market. For testing; the electronic circuit to be provided to control the movement of the main shaft according to dynamic intensity of solar radiations with respect to the time and the solar angle. The proposed system is portable and suitable for dynamic applications.

## ACKNOWLEDGEMENT

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