ANALYSIS OF SPIRAL PATH SINGLE ACTUATOR SOLAR TRACKING SYSTEM TO MAXIMIZE SOLAR PANEL OUTPUT

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Abstract- Energy plays a vital role in economic development of any country. Now a day's Most of the investment is being done in energy sector by Developed and Developing countries. Major share in National imports is by Energy. Basically large share of fossil fuel is getting used to generate electricity. Day by day the Electricity demand is going to increase due to high industrialization as civilization. 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. Light energy is getting converted in to Electricity with the help of Photovoltaic Panel. But the Efficiency of the PV cells is low as compare to other energy generation system. There are various governing factors which decide the efficiency of the PV panel like temperature, type, mounting, etc. If mounting is considered there are two types of systems available in market: fixed & moving. Fixed panels are less efficient than moving panels. Moving systems are called as solar tracking systems. Further the solar trackers are available in two type's single axis and two axes. 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 system is based on single drive giving out put in rotary as well as linear motion. Spiral path actuator is developed and being used to orient the PV panel so that optimum output can be obtained. Proposed system is less costly, more efficient and can be used for other applications. Design and FEA of the system is done for critical components.

Index terms - Solar Tracker, Solar Panel, Sun Tracker, Solar Tracking System.

I. INTRODUCTION

For the last two centuries, fossil fuel has been considered and utilized as the main source of energy. However; the negative impacts of burning fossil fuel on the environment have forced the energy research continuity to seriously consider renewable sources of energy. Solar energy, in particular, has been the main focus in this regard because it is a source of clean energy and naturally available. Solar energy applications include solar photovoltaic and solar thermal. Solar thermal systems are used to power absorption refrigeration and air cooling systems.Since the primary energy resources are getting deplete day by day. 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 fulfill such huge consumption in future? Only one most beneficial option is Renewable energy. Renewable energy resources are inexhaustible and green. Examples of renewable resources include wind power, solar power, geothermal energy, tidal power and hydroelectric power. The most important benefit of renewable energy is negligible pollution. 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 plants are green, non polluting the environment [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.

II. LITERATURE REVIEW

A. Background and Problem definition

The maximum output can be obtained by directing the panel to the direction of sun. There are many variable for the direction of the sun like seasons. First case is the panel is adjusted in season wise. Solar panels should always face true south if you are in the northern hemisphere, or true north if you are in the southern hemisphere. Actual difference should be

adjusted according to the place. The graph below shows the effect of adjusting the tilt. The blue 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.

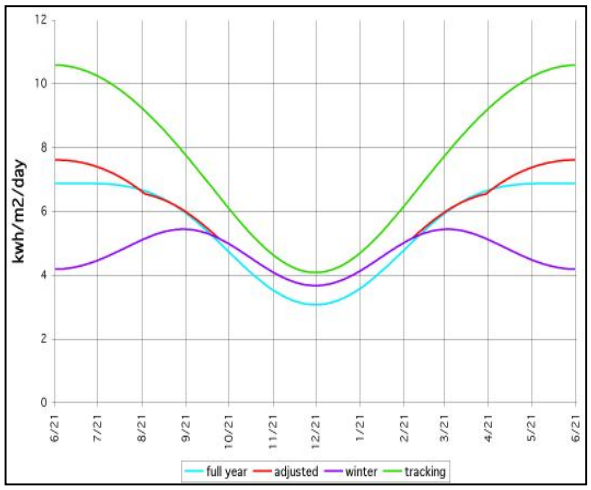


Figure 1. Effect of Adjusting the Tilt [10]

How should common user change the angle of the panel? Also how many times one can change the tilt? These are some practical problems or complexion in the system arises which result in the more complicated system design.

B. Present solutions & Need

There are various two axis solar trackers are available in market. But these systems are costly and complicated. Most of the systems are governed by solar a calculation which drives the electromechanical parts. These calculations are based on the solar maps for particular place. So the applications are specific, costly, and bulky. Hence there is need to develop alternative solution that will be more efficient, simpler than the existing.

III. METHOD OF ANALYSIS

A. Selection of Mechanism

The mechanism selected is the high speed spiral scanner used in the RADAR application. The output of the mechanism is the spiral path. 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 above. The Main shaft is denoted by B tend to rotate by 60RPM by dc motor. The output end J is moving to its zero position to maximum output position for every 40 revolutions from main shaft B. Carrier A is assembled with the end portion of the B. Helical Gear C with 40 teeth is assembled on carrier and meshes with the worm threads in the housing E. Cam F is fitted with gear C. Spherical section G is resting on balls which gives tilting and conic motion. While operation the gear C and Cam F moves as an assembly as per input received by main shaft B which give the output at end J as a 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. As Gear and cam are rotating around the gear axis, the output angle of the is continuously changing which produces the spiral scanning motion. Again new cycle will be generated when the cam is returned by the spring.

B. Mechanical Design of Critical Parts

Material Selected is EN24 for all mechanical parts.
Maximum torque = 4.77 N-m
No of teeth on gear =40
Module = 2 mm
Radius of gear by geometry = 40 x2 /2 = 40 mm
Maximum load = T/r = 4.77 x 103 /40 =119.2 N
b = 10 m
Material of spur gear and pinion = EN 24
S_{ut} pinion = Sut gear = 850N/mm^2
Service factor (Cs) = 1.5
$\Rightarrow$Pt =(W x Cs) = 178 N.
P_{eff} = 178N (as Cv =1 due to low speed of operation)
P_{eff} = 178 N --------(A)
Lewis Strength equation
WT = Sbym
Where;
Y= 0.484 – 2.86/Z
$\Rightarrow y_p$ = 0.484 - 2.86/40 = 0.4125
$\Rightarrow S_{yp}$ = 49.08
As $\Rightarrow$ pinion is weaker
WT = (Syp) x b x =49.08 x 10m x m
WT= 490.8m^2----------(B)
Equation (A) & (B)
490.9 m^2 = 40$\Rightarrow$ m=0.285 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.

According to ASME code permissible values of shear stress may be calculated from various relations.
$\tau = 0.18\ S_{ut} = 0.18 \times 800 = 144$ N/mm^2
OR
$\tau = 0.3\ S_{yt} = 0.3 \times 680 = 204$ N/mm^2
Considering minimum of the above values;
$\Rightarrow\ \tau_{all} = 144$ N/mm2
Torque at motor shaft = 0.8 N-m
$\Rightarrow$ T = 0.8 N-m
Check for Torsional Shear Failure of Shaft.
Assuming minimum section diameter on input shaft = 6mm

$\Rightarrow$ d = 6mm

Td = $\Pi/16 \times \tau$ $fs_{act} \times d^3$

$\Rightarrow \tau_{act} = 16/\pi \times Td/d\ 3$

$= 16/\pi \times 0.8 \times 10^3 / (6)^3$

$\Rightarrow \tau_{act} = 18.86\ N/mm^2$

As $\tau_{act} < \tau_{all}$ $\Rightarrow$ Thus, tilt shaft is safe under torsional load

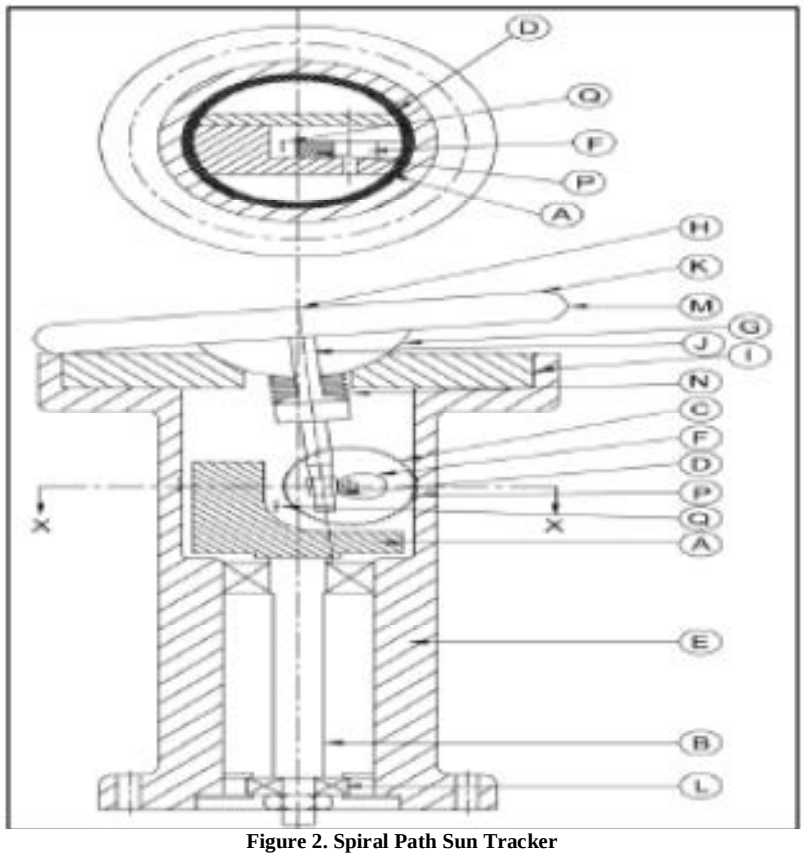


Figure 2. Spiral Path Sun Tracker

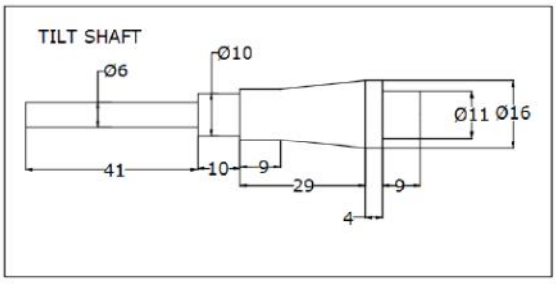


Figure 3. Tilt Shaft

According to ASME code permissible values of shear stress may be calculated from various relations.

$\tau = 0.18\ S_{ut} = 0.18 \times 800 = 144\ N/mm^2$

OR

$\tau = 0.3\ S_{yt} = 0.3 \times 680 = 204\ N/mm^2$

Considering minimum of the above values;

$\Rightarrow \tau_{all} = 144\ N/mm^2$

Shaft is provided with dimples for locking; this will reduce its strength. Hence reducing above value of allowable stress by 25%

$\Rightarrow \tau_{all} = 108\ N/mm^2$

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

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

Check for torsional shear failure of 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

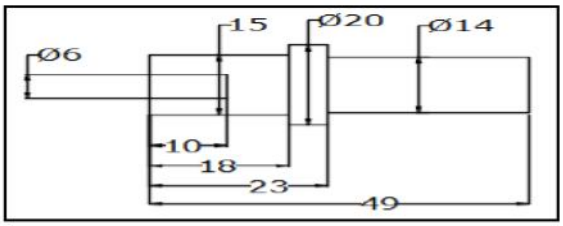


Figure 4. Main Shaft

C FEA OF CRITICAL PARTS

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

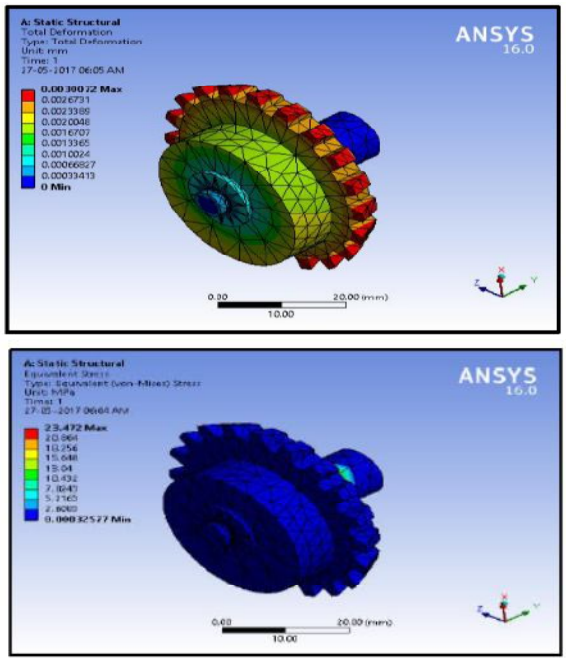


Figure 5. Gear – Cam Assembly FEA

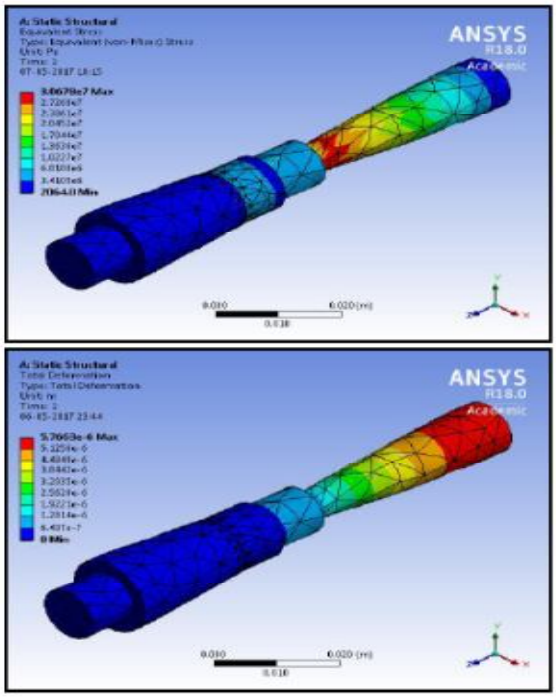


Figure 6. Tilt Shaft FEA

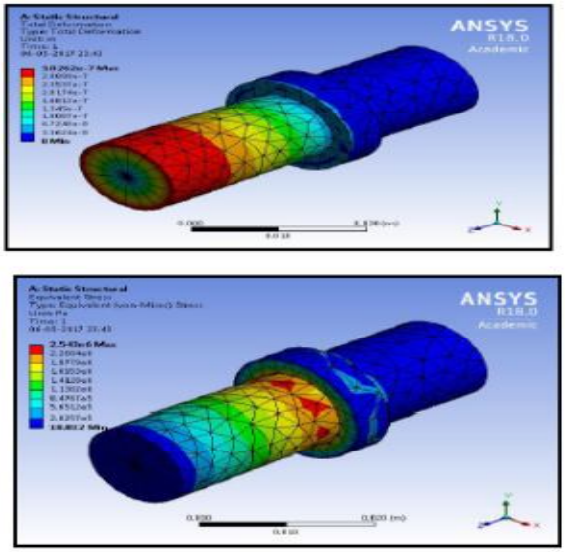


Figure7. Main Shaft FEA

D. OUTPUT ANGLES

For the finding output angles the graphical analysis is done with the actual design dimensions. The line diagram of mechanism is shown below.

Cam is divided in to 6 degrees and the results obtained are.

Sr. No.	Position of Cam	Tilt Achieved
11	0°	7.1°
22	60°	3.8°
33	120°	3.9°
34	180°	7.1°
55	240°	10.0°
66	300°	9.76°

Table 1.Tilt Achieved according to Cam Position

E. AUTOMATION

Electromechanical arrangement to be provided such that the tilt will be controlled by the intensity sensor i.e PV Panel. The general arrangement will be...

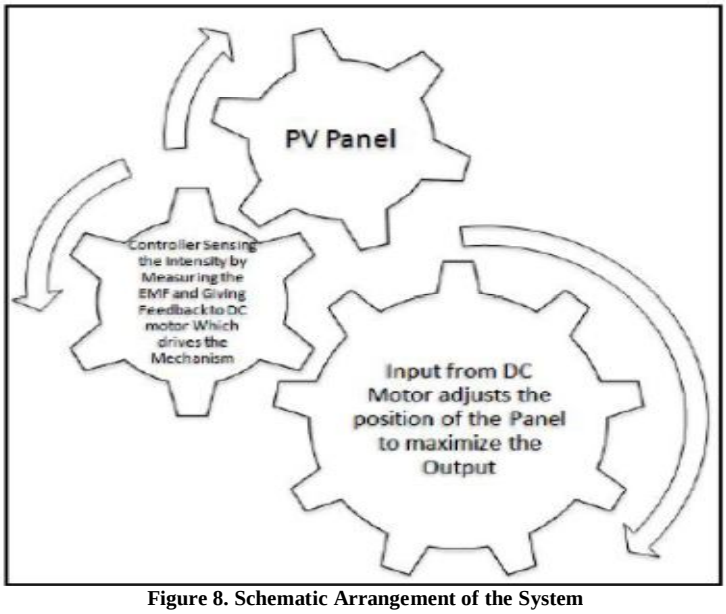


Figure 8. Schematic Arrangement of the System

IV. RESULTS AND DISCUSSION

Mechanical design is done and the material selection with validation from the FEA software. So the components are safe.

Part Name	Max Theoretical Stress N/mm²	Von-misses Stress N/mm²	Maximum Deformation (m)	Result
Main Shaft	1.48	2.50	3.02 E-7	Safe
CAM	49.00	23.47	3.00 E-6	Safe
Tilt Shaft	18.86	30.6	5.70 E-6	Safe

Table2.Results

The Maximum tilt can be achieved from above arrangement is 10°.

CONCLUSION

This arrangement is working on the single drive. So the second drive is eliminated this is the advantage of the system. The performance of the system is depends upon the better electrical support. The proposed arrangement spiral path single actuator solar tracker for better output is designed. There is scope of optimization in material to reduce cost as well as weight. This system can be use for solar thermal applications. As the solar calculations are not considered in the process, hence the system become simpler in use and suitable for any place.

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