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Analysis and Synthesis of Solar Tracker using Timer Mechanism

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***Abstract*— Utilizing renewable energy sources in an effective manner is essential, to give a healthy environment and to show an alternative for fossil fuel for the next generation. Those sources are inexhaustible, sustainable and free of cost. To increase the irradiance on solar panel an attempt has been made to tilt solar panel from dawn to dusk, using a solar tracker which works on the basis of gravitational potential energy. Driving of solar tracker can achieve using timer mechanism. Moment of solar panel relates with the position of sun, earth as the frame of reference. One axis tracking of sun can be achieved by using this mechanism**.

Index terms - Renewable Energy, Solar Tracker, Gravitational Potential Energy, Timer Mechanism, One Axis Tracking.

I. INTRODUCTION

In the present scenario usage of energy in an effective and efficient way is very essential. Sun is most renewable energy source available in nature. The energy received by the earth from the sun in one hour is greater than the world population uses in a whole year and it is free of cost. A place gets plenty of sunlight due to its proximity to the equator. The conversion principle of solar light into electricity, called Photo-Voltaic or PV conversion, is not very new, but the efficiency improvement of the PV conversion equipment is still one of top priorities for many academic and/or industrial research groups all over the world.

Solar panel gives maximum power output throughout the year if it installed at a tilt angle which is equal to the latitude of that place. To get maximum insolation with respect to seasons the tilt angle deviates a little from the latitude angle. In hot summer days, solar panel must be installed in a place where it receives maximum air currents so that its temperature remains low and power output remains high [1].

To improve the efficiency of PV conversion, many solutions evolved among those we can mention solar tracking [2], [3], [4] invention of new equipment [5], new materials and technologies [6], [7].

Our objective is mainly concentrated on solar tracking system. Even though a fixed flat-panel can be set to collect a high proportion of available noon-time energy, significant power is also available in the early mornings and late afternoons. So solar tracker plays a significant role to increase the insolation.

There are two basic types of tracking system. Single-axis trackers simply rotate about one axis, azimuthally moving from east to west over the course of a day. Double-axis trackers rotate both east to west and zenithally (vertically) [8]. These are latitude-dependent, but compared with modules fixed at the optimum angle, single-axis trackers typically increase electricity output by between 27%–32%.

Solar tracker drives, can be divided into three main types depending on the type of drive and sensing or positioning system that they incorporate.

• 1. Passive trackers: use the sun's radiation to heat gases that move the tracker across the sky. It won't consume any energy.
Gas tracker very rarely points the solar panel directly to the sun, due to the temperature varies from day to day and Overcast days are also a problem can damage the panel.
• 2. Active trackers: use electric or hydraulic drives and some type of gearing or actuator to move the tracker. Those are expensive.
• 3. Open loop trackers: use no sensing but instead determine the position of the sun through prerecorded data for a particular site [9].

Present paper deals with open loop tracker in which a timer is used to move the tracker across the sky. Incremental movement throughout the day keeps the solar panel pointing the sun. The mechanism consists of timer which creates mass imbalance, which helps to tilt the panel.

II. Analysis

A. To fix required motion

The panel has to rotate according to sun position, according to that panel has to achieve angular velocity of earth. So angular velocity of panel should be constant. In ideal case, if no friction exists between surface of panel and air and friction between kinematic pairs, then there is no energy loss. Then mass of another side of tracker acts as resistance to force. So that we can calculate the velocity it attained at last. And due to mass imbalance, moment of tracker takes place with some angle. We can estimate how much energy need to supply to make constant angular displacements. But in real case, we need to calculate static friction and then kinetic friction. Because different energies we have to supply at initial interval and once it attains motion. Earth rotates 15^o in an hour so it is very minute. That is why it is better to consider effect of static friction every time. Then no need to consider two mass flow

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rates. So that we can calculate how much energy need to supply per second. To consider ideal case we have to neglect frictional effect at joint. For that we have to provide best lubrication. Here we are considering ideal case.

B. For single axis tracking

Two Knuckle joints can use.one for fixing the latitude angle and another for track the sun azimuthally. To calculate the direct irradiation of sun we are implying a case of arbitrarily oriented surface. And panel can arrange at some fixed height from ground. The basic astronomical data is required in calculations.

C. Designing of solar tracker

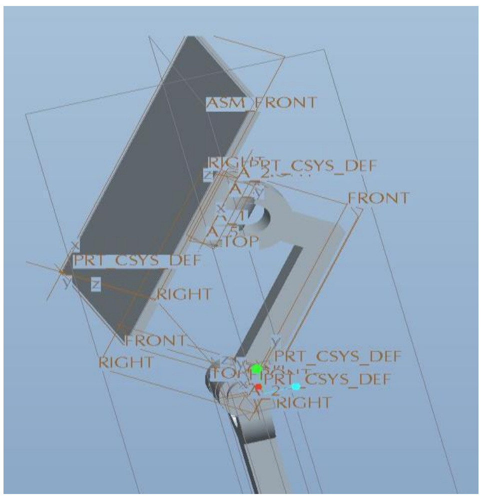

Fig. 1 Solar tracker modeled in pro engineer

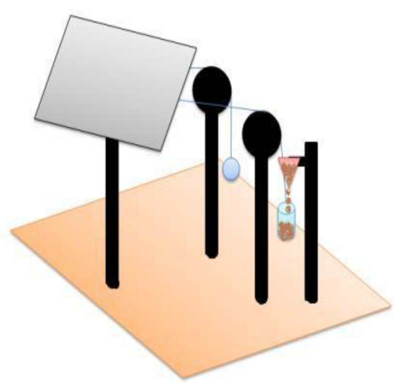

Fig. 2 A simple model of solar tracker (Sketched in MS Power Point 2010)

Face part of solar tracker, where panel situates can be design with aluminum for light weight purpose. Remaining part of tracker can be design with steel. The modeled solar tracker has shown in figure 1. V grooved pulley can use here for good power transmission. Round belt can use, because it is a light duty and the sample model of solar tracker equipment has shown in figure 2.

D. Modeling of timer

In order to model timer, it is necessary to make some simplifying assumptions. Timer consists of sand which flows with respect to time. The primary assumption is to treat the sand as a fluid. Both dry sand and liquids similarly display continuum behavior, which refers to materials behaving macroscopically, as opposed to the dynamics of individual particles. Sand behaves in this way due to air voids between grains, which keeps them apart and reduces friction.

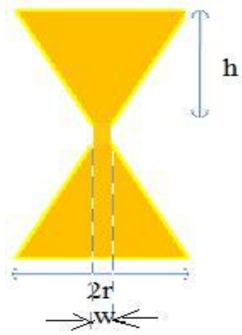

Fig. 3 simplified shape of a sand timer.
(Sketched in MS paint 2010)

This allows the sand to flow freely in a similar way to fluids, thus justifying the initial assumption. By treating the sand as a fluid, it is possible to use fluid dynamics to find the time taken for a volume of sand to pass through the sand timer. It is also necessary to simplify the shape of the sand timer. The sample model of sand timer has shown in figure 3. It consists of two conical sections, of radius r and height H, joined by a small cylinder of diameter w, where w is significantly smaller than both r and This model assumes that the volume of sand completely fills the upper cone, and that the volume cut off at the tip of the cone by the gap is negligible [10].

III. Synthesis

A. Evaluation of angular velocity of the solar panel

According to the analysis the angular acceleration is calculated and it is shown below.

Angular acceleration = 0.000014546 rad/sec

The whole mass of solar tracker's face taking density of Aluminum as 2.7 g/cc = 12.5938 kg

Moment of Inertia of modeled Solar tracker's face about its Centre of Mass = 1.0128 kg m^2

B. Evaluation of amount mass in timer based on day time of that day

F is the increment of force required on one side of the panel to get desired angular velocity
As per our analysis. l is the length of the solar panel. Hence from the dynamic analysis –

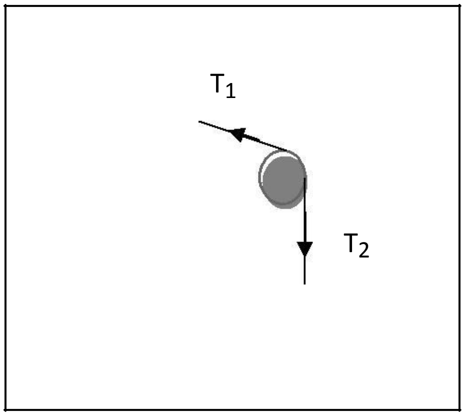

Fig. 4 Tensions in pulley
(Sketched in MS Word 2010)

Since gradual increase of sand mass, the tension T_2 in the V-grooved pulley increases gradually, which has shown in figure 4 and it is calculated as follows

= wrap angle; = Coefficent of friction
α = Groove angle
$\alpha = 22.5^0$
Coefficient of Friction rope on a Cast Iron is μ=0.12
ρ_{Sand}= 1780 kg/m^3
Volume flow rate required
Some sample calculations were done to calculate the weight of mass in timer.
For March 21st:

Sunset is 5hours 59minutes 25seconds
Total Seconds = 21565 seconds
Weight of mass to fix in timer =

0.03828kg ***C. Design of sand timer mechanism***

Now sand has to be poured through the cylinder of timer and the diameter of the cylinder calculated as follows
Assuming height of the sand timer mechanism as 30cm from center to one end of the cone and considering sand flow as an incompressible fluid and in steady flow.
Applying Bernoulli's Equation

+ 2 + = Diameter of the cylinder = 0.01618 .

D. Calculation of solar irradiation on panel of different cases

Basic solar angles and derived solar angles used to calculate solar irradiation on solar panel.

TABLE 1. Altitude and Azimuth Angles on March 21st, 2014, Nuzvid.

Time	Altitude Angle (β)	Azimuth Angle (γ)
7:00 A.M.	14.35	94.84
8:00 A.M.	28.59	99,92
9:00 A.M.	42.57	106.64
10:00 A.M.	55.92	117.26
11:00 A.M.	67.43	138.03
12:00 P.M.	72.83	180.49
01:00 P.M.	67.33	222.26
02:00 P.M.	55.79	242.88
03:00 P.M.	42.44	253.43
04:00 P.M.	28.45	260.13
05:00 P.M	14.21	265.20

TABLE 2. I_{DN} values according to respective altitude angles (β) on March 21st, 2014, Nuzvid.

Time	(W/m^2)
7:00 A.M.	632.0160
8:00 A.M.	856.067
9:00 A.M.	941.749
10:00 A.M.	982.395
11:00 A.M.	1001.648
12:00 P.M.	1007.336
01:00 P.M.	1001.525
02:00 P.M.	982.110
03:00 P.M.	941.211
04:00 P.M.	854.810
05:00 P.M	628.180

Case 1: Solar Panel is parallel to the earth surface on the location and not rotating

TABLE 3.Values of incident, cosine, Cosine Irradiation on March 21st, 2014, Nuzvid.

Time	Incident Angle (θ)	Cos(θ)	
7:00 A.M.	75.65	0.2478	156.6135
8:00 A.M.	61.41	0.47853	409.653
9:00 A.M.	47.43	0.6764	636.99
10:00 A.M.	34.08	0.8282	813.619
11:00 A.M.	22.57	0.92345	924.9718
12:00 P.M.	17.17	0.955	962.0058
01:00 P.M.	22.67	0.922	923.40605
02:00 P.M.	34.21	0.826	811.223
03:00 P.M.	47.56	0.674	634.376
04:00 P.M.	61.55	0.476	406.8895
05:00 P.M	75.79	0.245	153.9041

Case 2: Solar Panel is making angle of latitude angle with earth surface and not rotating

TABLE 4. Values of incident, cosine, Cosine Irradiation on March 21st, 2014, Nuzvid.

Time	Incident Angle (θ)	Cos(θ)	
7:00 A.M.	74.877	0.26088	164.88
8:00 A.M.	59.878	0.5018	429.57
9:00 A.M.	44.88	0.708	666.758
10:00 A.M.	29.88	0.86	844.8597
11:00 A.M.	14.87	0.96	961.58
12:00 P.M.	0.415	1	1007.336
01:00 P.M.	15.027	0.965	966.4716
02:00 P.M.	30.030	0.865	849.52
03:00 P.M.	45.021	0.7068	665.248
04:00 P.M.	60.025	0.4996	427.063
05:00 P.M	75.022	0.258	162.0704

Case 3: Solar Panel is making angle of latitude angle with the location and rotating around the surface normal

TABLE 5. Values of incident, cosine, Cosine Irradiation on March 21st, 2014, Nuzvid.

Time	Incident Angle (θ)	Cos(θ)	
7:00 A.M.	58.87	0.516	326.12
8:00 A.M.	44.63	0.711	608.66
9:00 A.M.	30.65	0.860	809.90
10:00 A.M.	17.30	0.954	937.20
11:00 A.M.	5.79	0.994	995.63
12:00 P.M.	0.39	.999	1006.32
01:00 P.M.	5.89	0.994	995.51
02:00 P.M.	17.40	0.954	936.93
03:00 P.M.	30.78	0.859	808.50
04:00 P.M.	44.78	0.709	606.06
05:00 P.M	59.01	0.514	322.88

IV. Results and Discussions

The increment of force required on one side of the panel to get desired angular velocity = 3.1352×10^{-5} N
Volume flow rate required for approximate constant tilt of panel is $=4.987388\times 10^{-10} m^3/s$

The required amount of mass to fix in the timer on March 21st= 0.03828kg

A. For case1

Average value of $I_{DN}\cos\theta$ = 621.24645 W/m^2

Root Mean Square value of $I_{DN}\cos\theta$ = 683.8090 W/m^2

B. For case2

Average value of $I_{DN}\cos\theta$ = 648.668 W/m^2

Root Mean Square value of $I_{DN}\cos\theta$ = 714.83 W/m^2

C. For case3

Average value of $I_{DN}\cos\theta$ = 759.428W/m^2

Root Mean Square value of $I_{DN}\cos\theta$ = 798.26 W/m^2

D. Percentage Increase in input by Averages

Table 5. Percentage increase of input of different cases by average method

Case 3 over Case 2	14.5%
Case 2 over Case 1	4.227%
Case 3 over Case 1	18.19%

E. Percentage Increase in input by RMS

Table 6. Percentage increase of input of different cases by RMS method

Case 3 over Case 2	10.45%
Case 2 over Case 1	4.33%
Case 3 over Case 1	14.33%

For a given panel of weight we have to design a tracker's face where we place the panel. Here we have taken combined mass i.e. base for panel and panel as 10kg for simplification. No gaps between these two. Based on day time, we have to change the amount of sand required to tilt panel completely to west. Depends on required amount of mass, construction of sand timer changes. One axis tracking has a significant effect to increase the irradiance on solar panel.

VI. CONCLUSION

It is possible to tilt the panel without consuming any high grade energy. We can overcome the problem, not precise tilting in sensing systems where there is a cloudiness. It is possible to tilt a panel with any dimension. It is environment friendly equipment. Dual axis tracking can also implement with this timer in future. It rotates continuously once we attached the weight of sand manually at the day beginning. It is depends on day time of that day. We can take care of Seasonal tilt also depends on declination angle but manually. We can use this equipment at small industries and at home also. It act as good supporter to survive at remote areas.

REFERENCES

[1]. Hanif M, M. Ramzan,,M. Rahman, M. Khan,M. Amin, and M. Aamir, Studying power output of pv solar panels at different temperatures and tilt angles,*ISESCO Journal of Science and Technology - Volume 8,Number 14 (November 2012) (9-12))*

[2]. Sanjay Sharma, Automatic sun-tracking solar cell array system**,** *International Journal of Advanced Engineering Research and Studies, E-ISSN2249 – 8974*

[3]. Dhanabal.R, Bharathi.V, Ranjitha.R, Ponni.A, Deepthi.S, Mageshkannan.P, Comparison of Efficiencies of Solar Tracker

systems with static panel Single-Axis Tracking System and Dual-Axis Tracking System with Fixed Mount, *International Journal of Engineering and Technology (IJET), Vol5, No.2, Apr-May 2013*

[4]. C.Saravanan, Dr.M.A.Panneerselvam,I.William Christopher, A Novel Low Cost Automatic Solar Tracking System, *International J.ournal of Computer Applications (0975 – 8887) Volume 31– No.9, October 2011*

[5]. http://www.crses.sun.ac.za/files/services/events/workshops/
03_Solar_Collectors.pdf

[6]. Md. Kafiul Islam, A N M MushfiqulHaque and Md. RezwanulHaque, Analysis of maximum possible utilization of solar radiation on a solar photovoltaic cell , *International Journal of Modeling and Optimization, Vol. 1, No. 1, April 2011*

[7]. AzharGhazali M.& Abdul Malek Abdul Rahman, The performance of three different solar panels for solar electricity applying solar tracking device under the Malaysian climate condition, *Energy and Environment Research; Vol. 2, No. 1; 2012, ISSN 1927-0569 E-ISSN 1927-0577)*

[8]. http://en.wikipedia.org/wiki/Solar_tracker

[9]. http://www.slideshare.net/harshi1990/solar-tracker

[10]. J. Sandhu, A. Edgington, M. Grant, N. Rowe-Gurney, A4_2 Sand Timers: A Hydro dynamical Approach, *Journal of Physics Special Topics*

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