Tracking of Solar Panel by Hydraulic system

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Abstract— Solar energy is the cheapest energy source. But the proper use of solar panels makes it more effective. Proposed theory gives advanced movable structure of solar panel with the help of hydraulic system. This paper presents the well-designed prototype with best results.
Key words: Solar Panel, Hydraulic System, Prototype

I. INTRODUCTION

A. Solar Energy:

In modern sugar industries total automation is provided. Energy from the sun travels to the earth in the form of electromagnetic radiation similar to radio waves, but in a different frequency range called solar energy. Solar power is the conversion of received solar radiation into usable energy. It is a process that consists of harnessing the sun's present emissions ofheat and/or light. This heat and light are the effects of the sun's constant nuclear fusion of hydrogen nuclei. The process of fusion produces helium nuclei as well as large amounts of energy.

Fig. 1: Solar Energy

Available solar energy is often expressed in units of energy per time per unit area, such as watts per square meter (W/m2). The amount of energy available from the sun outside the Earth's atmosphere is approximately 1367 W/m2. Some of the solar energy is absorbed as it passes through the Earth's atmosphere. As a result, on a clear day the amount of solar energy available at

The Earth's surface in the direction of the sun is typically 1000 W/m2. The level of solar radiation a region receives depends on latitude and local weather conditions.

B. Solar Tracking:

Solar tracking is the process of varying the angle of solar panels, to take advantage of the full amount of the sun energy.

In remote places sun is the cheap source of electricity. The output from solar panel depends on the intensity of sunlight falling on it and also on the angle of incidence. It means to get maximum efficiency; the solar panel must remain in front of sun during the whole day. But due the rotation of earth the panel can maintain their position always in front of sun. Thus to get maximum and a constant output, a system is required which should be capable to constantly rotate the solar panel supply is the first and the most important part of our project. Here +5v regulated power supply is used.

Fig. 2: Solar panels

C. Electrical Solar Tracking Systems:

The most of today's Solar tracking systems are electrical systems. Elements of these systems are an electric servo drive and an electronic control system. The electric servo drive includes a stepper motor, which rotates the solar panels with a preset angular displacement. The control system gives an input signal to servo drive system to drive the stepper motor with the help of sensor and electronic counters.

In these systems, the major portion of energy produced by the solar panel is utilized for tracking operation. If not, these systems should have a battery storage unit or should be connected to power supply grid or the combination of both.

II. THEORY OF PROJECT

A. Hydraulic Actuator (Hydraulic Cylinder):

The actuators are used in hydraulic systems to convert the fluid energy (i.e. fluid with high pressure) back into mechanical energy by reducing the pressure of fluid. The power developed by the actuator depends on,

1) Flow rate
2) Pressure drop across the actuator
3) Efficiency of actuator

There are three types of hydraulic actuators,

1) Linear actuators
2) Rotary actuators (Continuous)
3) Rotary actuators (Limited angle)

Linear actuators are nothing but hydraulic cylinders, which produce straight line motion.

The linear motion achieved in a hydraulic cylinder depends on the stroke length. These actuators are generally termed hydraulic cylinders. Other specific terms like rams and jacks are also used for hydraulic actuators, depending on their end use. The term ram is used for single acting cylinder that causes linear motion in horizontal plane and the term jack refers to a hydraulic cylinder that is used to lift the loads.

The common types of linear actuators are,

1) Single acting cylinder
2) Double acting cylinder
3) Displacement cylinder

B. Double acting cylinder:

Double acting cylinder produces linear motion in two directions. Hydraulic power is applied on either side of the piston. The construction of double acting cylinder is similar to single acting cylinder except that rod end of the cylinder also has oil port.

The constructional details of the double acting cylinder is as shown in figure 3.

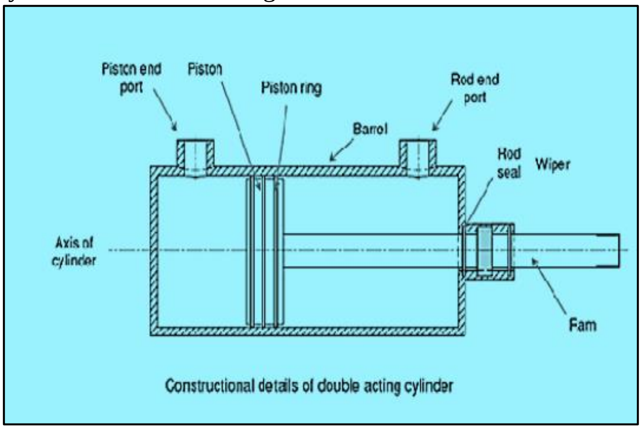

Fig. 3: Constructional details of double acting cylinder

Double acting cylinder has a hollow cylinder (barrel), piston and piston rod. Both the ends are sealed with the end caps, which are either threaded or welded to the main cylinder.

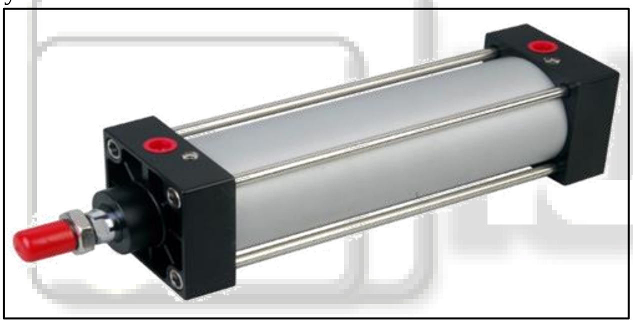

Fig. 4: Actual Double acting cylinder

In some designs, the end caps are held with the cylinder by tie rods. The piston is provided with a piston seal, commonly used are piston rings to protect the leakage of oil. The rod is provided with seal to protect the leakage, a bearing to carry the radial loads, a wiper to protect the foreign particles like dust entering into cylinder. Oil ports are provided on either side of the piston, so that the fluid pressure can be applied alternatively on both the sides.

C. Flow Control Valve (FCV):

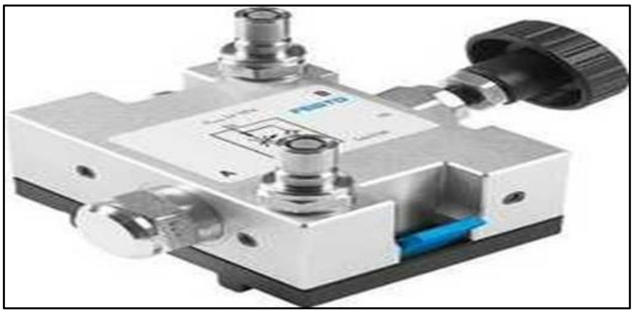

Fig. 5: Flow Control Valve

The function of flow control valve is to regulate the flow rate of fluid in a hydraulic system.

This in turn used to control the speed of actuator/s. These valves are basically variable area orifices, in which increasing the area of orifice increases the flow rate and decreasing the area of orifice reduces the flow rate.

The common types of FCVs are,

1) Simple needle valve
2) Needle valve with integral check
3) Pressure compensated FCV

D. Check Valve:

Fig. 6: Check Valve

Check valves are also known as directional control valves. The function of check valve is to direct the free flow in only one direction, and block any flow in reverse direction. These are similar in operational analogy of electronic diodes. The three types of check valves are generally used.

1) Ball type valve
2) Poppet type valve
3) Pilot operated check valve

A spring operated direction valve requires a small pressure to open, which iscalled as cracking pressure. Due to this it can work like low pressure relief valve to some extent.

After some time it touches the ground. The car starts lifting. If it is lifted above the ground, then stop motor M1 and start M2. M2 will turn the car as per requirement. If 1800 rotation is completed then stop this motor and again start M1 in reverse direction. The car rests on the ground floor and the jack assembly include inside the car.

E. Filter:

Filters are used in hydraulic systems to remove both the solid and liquid contaminants. Filter is a device that consist of an element (called filter element) having the openings. When the contaminated oil passes through the filter element, the particles remain/get filtered, while the clean fluid passes out of the element. Filter elements are available in sizes as small as 1 micron, which mean even a dust particle of size 1 micron gets filtered through this filter element.

The three common types of filter elements used in hydraulic systems are,

1) Mechanical elements
2) Absorbent elements
3) Adsorbent elements

The types of filters are,

1) Full-flow filter
2) Proportional-flow filter

F. Hydraulic Oil:

Fig. 7: Hydraulic Oil

The working fluid in all hydraulic systems is a fluid. Various oil based fluids which had thedesirable properties were developed for the use in hydraulic systems.

The functions of the hydraulic fluid are,

1) To transmit power, this is the primary function.
2) To lubricate various moving parts, so as to avoid metal-to-metal contact, and reduce wear and noise.
3) To carry the heat generated in the system due to friction between moving parts and moving fluid and to dissipate to the environment either through a suitable heat exchanger or through the reservoir.

G. Reservoir:

Fig. 8: Reservoir

Reservoirs are basically storage tanks for the hydraulic oil. The functions of a hydraulic reservoir are,

1) To act as a storage tank.
2) To provide heat exchange, thus cooling the oil.
3) To allow entrained air to escape from fluid.
4) To allow fluid contaminations to settle down.
5) To make-up any leakages in the system.
6) To provide filling point for the system.

The reservoir design should be optimum. A smaller size reservoir then required causes problems like overheating, increased contamination, higher wear and tear. An oversized reservoir will increase the cost of tank and longer warming period.

III. CONSTRUCTION DETAILS

The arrangement of the hydraulic components and other mechanical elements are illustrated by the following schematic diagram.

The components of the system are,

1) Panel seat
2) Column
3) Base
4) Weight
5) Weight holder
6) Double acting cylinder
7) Check valve
8) Flow control valve
9) Reservoir
10) Filter
11) Rod end mounting
12) Piston end hinge
13) Handle
14) Counter weight platform
15) Connecting hose
16) T-Connector
17) Stopper

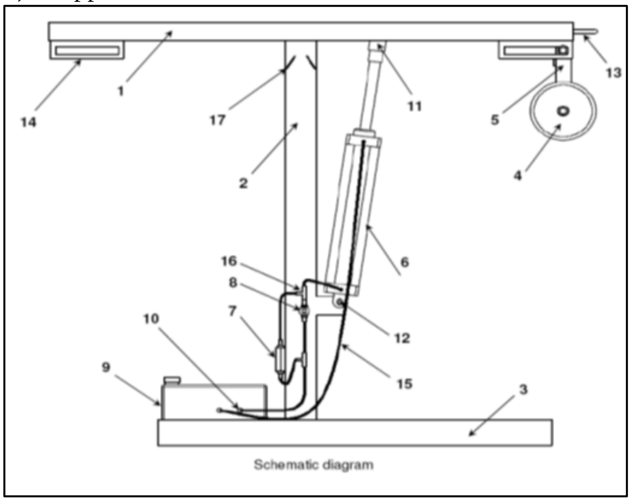

Fig. 9: Construction Detail

IV. WORKING PRINCIPLE

Working procedure of the designed tracking system is explained by the hydraulic circuitdiagram and by the schematic diagrams.

A. Tracking:

As the tracking weight acts on the piston through piston rod, it pushes the oil out of thecylinder and the oil flows towards reservoir. While, due to the restricted cross sectional area at flow control valve the piston moves with the velocity equal to calculated tracking velocity. During this action the check valve remains closed, hence oil is allowed to flow only through flow control valve.

At the rod end of the cylinder, the oil is sucked into cylinder due to the vacuum pressure created by the applied weight

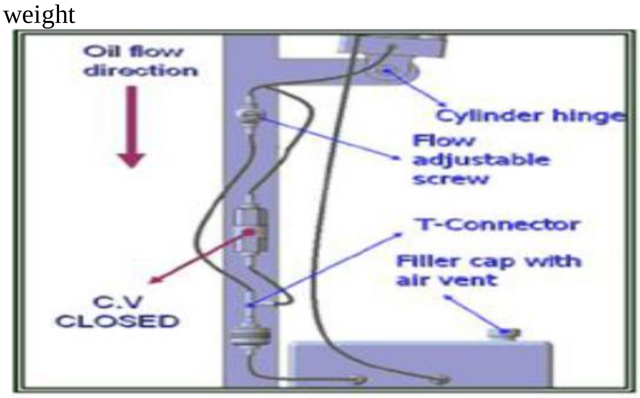

Fig. 10: Tracking

B. Return:

As the tracking time finishes, the panel seat has to be rotated by applying the torque, manually, to bring back into initial position. The vacuum pressure is created at piston end chamber and oil from reservoir rushes towards cylinder. As soon as the system pressure exceeds the cracking pressure of check valve, check valve opens and allowing full flow of oil from it, reducing the time required for repositioning operation.

The flow control valve also allows the oil to flow from it, increasing rate of flow and reduced panel repositioning time. At rod end of cylinder the piston forces the oil. The oil pressure increases and oil flows out of the cylinder. Oil returns to reservoir through a filter placed in the return line.

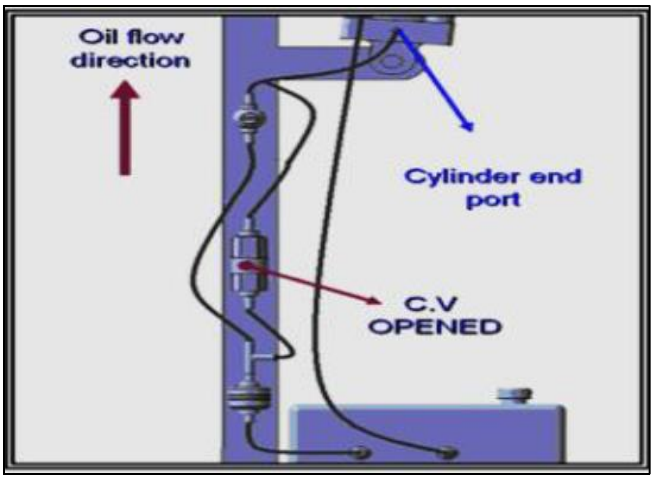

Fig. 11: Return

The lever mechanism used for the current tracking system is illustrated by the figure 12.

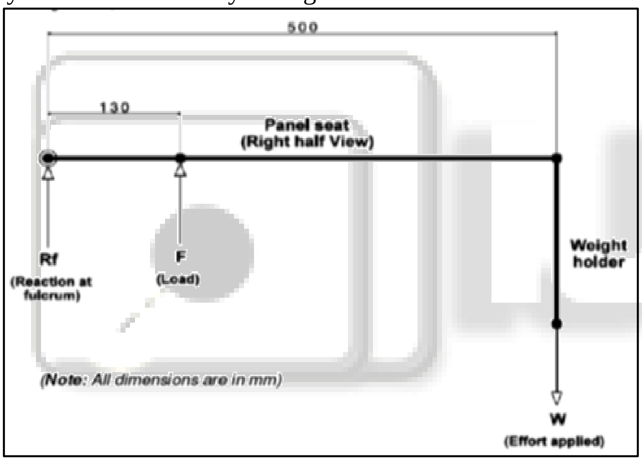

Fig. 12: Lever Mechanism

C. Tracking Mechanism:

Here, the load is the resistance offered by the cylinder for displacement, which whiledepends on the rate of flow from the cylinder. The weight of the disc is the applied driving force, hence it is the effort applied on the system to perform the desired operation. The weight is applied through a weight holder. Comparing with the types of lever systems, as the load is between fulcrum and effort point, this is a system with second type lever system. The arrow on the points shows the direction of force.

V. DESIGN OF PROJECT

A. Material Selection:

To prepare any machine part, the type of material should be properly selected, considering design, safety .The selection of material for engineering application is given by the following factors:-

1) Availability of materials
2) Suitability of the material for the required components.
3) Cost of the materials.

The machine is basically made up of mild steel. The reasons for the selection are Mild steel is readily available in market .It is economical to use and is available in standard sizes. It has good mechanical properties i.e. it is easily machinable. It has moderate factor of safety, because factor of safety results in unnecessary wastage of material and heavy selection. Low factor of safety results in unnecessary risk of failure. It has high tensile strength, low coefficient of thermal expansion. The materials of the sheets to be cut are taken as aluminium and plastic as they are replacing many metals in the present scenario because of their distinguished properties and features.

B. Hydraulic System Designs:

The details of calculation steps for the hydraulic system design are given as below,

Nomenclature:
D = Cylinder diameter in m
A = Cross sectional area of cylinder in m2
L = Length of stroke in m
d = Diameter of orifice in m
Cd = Co-efficient of discharge for orifice
Vp = Velocity of piston in m/s
Vo = Velocity of oil at orifice in m/s
Qc = Cylinder discharge in m3/s
Qo = Orifice discharge in m3/s

C. Return:

P = System pressure in N/m2
F = Force in N
W = Weight in N
r = Density of hydraulic oil in kg/m3
a = Distance from rod end to panel hinge in m
b = Distance from loading point to panel hinge in m

D. Available data:

Time range = 8 AM to 4 PM (8Hrs)
Pressure drop across the check valve = 50.8 mm Hg = 6772.77 N/m2
Pressure drop across the filters = 1 inch of Hg = 3386.38 N/m2
Size of the panel (L x B x H) = 1 m x 0.5 m x 0.025 m
Selected Hydraulic oil = SAE20 W40
r = 880 kg/m3
D = 0.05 m and A = 0.00196 m2
L = 0.21 m
d = 0.001 m
Cd = 0

E. Calculations:

Velocity of piston
Vp = Stroke length / Time range
= 0.21 / 28800
Vp = 7.29E-6 m/s
Cylinder discharge
Qc = Cross-sectional area A x Velocity of piston Vp
= 1.963E-3 x 7.29E-6
Qc = 1.43E-8 m3/s
Velocity of oil at orifice
By the relation for discharge from orifice,
Qo = Cd x a x Vo
1.43E-8 = 0.62 x 7.85E-7 x Vo
i.e.Vo = 0.029 m/s

System pressure
2 x P = Vo x r - - - - - - - (by V = (2gH)0.5& P = rgH)
2 x P = 0.0292 x 880
i.e.P = 0.37 Pa or N/m2
and also considering the pressure drop across the filters = 3386.68 Pa (Note: As check valve is closed during trackingoperation,pressure drop across check valve is not considered.)
The Total system pressure,
P = 0.37 + 3386.38
i.e.P = 3386.75 Pa
Force required,
F = P x A = 3386.75 x 1.963E-3
F= 6.64 N
F:Force required on the cylinder for tracking = 6.64 N

F. *Reservoir Design:*

Reservoir design is essential to determine the capacity of tank, hence to assure proper functionality. Some of the common rules to be followed in reservoir design are as follows,

1) The minimum size of the reservoir should be at least twice the pump delivery per minute.
2) Its capacity should be adequate enough to hold all the oil from the system that might drain into tank.
3) It should have oil level much above the intake strainer, so that no whirling effect will occur.
4) Its capacity should enough to allow for thermal expansion.

Displacement of cylinder,
Vc = (3.142/4) x D2 x L
= (3.142/4) x 0.052 x 0.21
Vc = 0.000412 m3
Volume of oil in hoses and other accessories,
Va = (3.142/4) x 0.012 x 0.6
Va = 0.0000471 m3
Theoretical volume of tank,
Vt = Vc + Va
= 0.000412 + 0.0000471
Vt = 0.00046 m3

As per optimum design practices, the actual volume of tank should be at least twice the theoretical volume of tank.
Hence, Minimum Volume of tank = 2 x Vt = 2 x 0.00046
i.e.Minimum volume of tank = 0.00092 m3 or 0.92 Liter

G. *Mechanical Design:*

Step 1: Tracking
Referring to the mechanism by the lever principles, taking reaction at fulcrum point,
We have,
Load x 0.13 m = Effort x 0.5 m
13.295 N x 0.13 m = W x 0.5 m - - - - - - - -(F = 13.295 N)
i.e.W = 3.456 N
Load required for the tracking operation = 3.456 N
and energy consumed for tracking,
Energy = Force x Distance (Cylinder displacement)
= 3.456 x 0.21
i.e.E = 0.725 J
Energy required for tracking operation = 0.725 J
Step 2: Return

The force applied for return operation is manual. Assuming a normal person can exert 5 kg of force against gravity, then
Force required for return operation = 49.05 N
Energy consumed for the return operation = Force x Angular displacement
= 5 x 9.81 x (_/180) x 0.5 x 120i.e. E = 51.36 J
Energy consumed for return operation = 51.36 J

H. *Results:*

The results obtained after the detailed calculations are given as below,
Velocity of piston = Vp = 7.29E-6 m/s
Cylinder = Qc = 1.43E-8 m3/s
Velocity of oil at orifice = Vo = 0.029 m/s
System pressure = P = 3386.75 Pa
The force required on the cylinder for tracking = F = 6.64 N
Considering mechanism for tracking,weight required for tracking,
W = 3.456 N
Energy required for tracking operation = 0.725 J
Force required for return operation = 49.05 N
Energy consumed for return operation = 51.36 J
Minimum volume of tank = 0.00092 m3 or 0.92 Liter
Increased power output and returns = 87.6 kW-hr worth of Rs.403/- (Considering a solar panel of area 0.456 m2 and analysis
period of 1 year)

I. *Assembly Details:*

Fig. 13: Assembly of the project

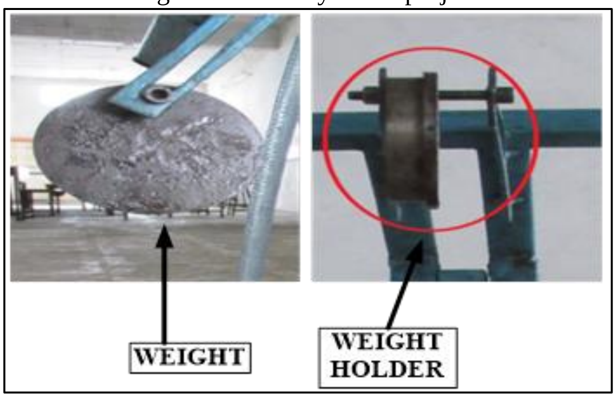

Fig. 14: Details of project

J. *Manufacturing Process Sheet:*

Sr No.	Description	Manufacturing process	Qty	Material
1.	Panel Seat	Cutting, slotting	01	Ms
2.	Column	Cutting	01	Ms
3.	Base	Welding	01	Ms

4.	Weight	Milling	01	Ms
5.	Weight Holder	Milling	01	Ms
6.	Double Acting Cylinder	-	01	Std
7.	Check Valve	-	01	Std
8.	Flow Control Valve	-	01	Std
9.	Reservoir	Welding	01	Ms
10.	Rod End Mounting	Welding	01	Ms
11.	Piston End Hinge	-	01	Ms
12.	Connector Hose	-	01	Std
13.	CounterWeight Platform	Milling	01	Ms
14.	T-Connectors	-	02	Std
15.	Hose Clips	-	20	Std
16.	Connector Nozzles	-	08	Std

Table 1: Material and Quantity

K. Cost Estimation:

Sr No.	Description	Qty	Cost
1.	Double Acting Cylinder	01	3150
2.	Check Valve	01	160
3.	Flow Control Valve	01	330
4.	T-Connectors	02	60
5.	Connector Nozzles	08	240
6.	Hose Clips	20	160
7.	Hose	3m	210

Table 2: Brought Out Material Cost

The cost of purchase parts = Rs. 4310/-

L. Miscellaneous Costs:

Operation	Cost(Rs)
Fabrication	1460
Gas Cutter	100
Total	1560

Table 3: Miscellaneous Costs

M. Machining Cost:

Operation	Rate Rs /Hr	Total Time Hrs	Total Cost Rs/-
Lathe	85	04	340
Milling	95	08	760
Drilling	60	3	180
Slotting	90	2	180
Total			1460

Table 4: Machining Cost

Brought Out Material Cost	=	4310/-
Maching Cost	=	1460/-
Miscellaneous Cost	=	1560/-
Raw Material Cost	=	3200/-
Total Cost	=	10530/-

VI. FEATURES

A. Advantages:

1) ‘Maximum utilization of solar panel , increased power generation; due to tracking the solar panel is exposed to the direction of sun at all the time , hence maximum utilization of panel takes place , and there by the power output increases.
2) Avoided electrical energy consumption for operation; for the tracking operation the present system uses only gravitational energy and there is no need of connecting to an electrical power source.Hence reduced capital cost and operating cost. The gravitational energy is uninterrupted and guaranteed supply of energy unlike the electrical supplies of storage.
3) Flexibility with size of panel ; due to the center hinge design , solar panel of different sizes and different weights can be mounted on this tracking system without any functional errors.
4) Robust and maintenance free for long run; the use of only mechanical components ensures high strength and robust in handling, which is not possible with use of electrical or electronic components.

B. Limitations:

1) Un-avoidable frictional loss at the hinge elements.
2) Non-automated as the manual effort is required for the return.
3) High initial cost.

C. Applications:

This project application is similar to the solar application like as

1) Solar heating systems
2) Solar cooking
3) Solar lighting
4) Solar thermal electric power plants
5) Solar design in architecture

VII. CONCLUSION

It is observed that the designed mechanical tracking system is a system, which consumes little energy for operation and contributing towards increasing the productivity of the solar panels.

This is the first attempt made towards utilizing the gravitational energy as a driving force for solar tracking systems and also in providing a suitable tracking system for the remote places.

In view of increasing demand for the electrical power, this tracking system can contribute a little (about 87.6 kw-hr per year) in the fulfillment this demand.

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