Design and Development of Mechanical Solar Tracking System

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Abstract — *In recent years, the growing global interest in the conservation of environment has provided a fresh motivation for research in the area of solar energy utilization. Already, installation of solar energy extraction devices such as solar panels, solar water heaters, solar cookers etc. is becoming popular in urban buildings. Most of these devices consist of a solar receptor that is kept facing the sun during the day, but the sun moves from east to west and the efficiency of the panel decreases. If one could trap this extra energy source then the efficiency of the solar panel would be increased. A tracking mechanism following the sun would achieve this aim. An attempt has been made to develop a simple yet efficient sun tracking mechanism using a motor, a speed reduction mechanism and real timer. The mechanism has been designed such that the sunrays falling on the panel are always perpendicular to the panel resulting in increase in efficiency of the electricity generation. This report presents, in detail, the design and construction adopted to develop the functional model that was fabricated and tested for performance which yielded the efficiency increase of 28.41% as compared to the conventional stationary panel position.*

Keywords—Motor, real timer, solar energy, speed reduction, sun tracking mechanism.

I. INTRODUCTION

Any physical activity in this world, whether by human beings or by nature is caused due to the flow of energy in one form or other? Energy is required to do any kind of work. Renewable energy is an indigenous resource available in considerable quantities to all developing nations and capable in principle, of having a significant local, regional or national economic impact. The use of renewable energy could help to conserve foreign exchange and generate local employment if conservation technologies are designed, manufactures, assembled and installed locally.

The sun radiates energy uniformly in all directions in the form of electromagnetic waves. When absorbed by a body, it increases its temperature. It provides the energy needed to sustain life in our solar system. It is clean, inexhaustible, abundantly and universally available renewable energy. Solar energy is also used by various well known natural effects and appears in nature in some other forms of energy. Solar energy has the greatest potential of all the sources of renewable energy and if only a small amount of this form of energy could be used, it will be one of the most important supplies of energy, especially when other sources in the country have depleted. Thus, solar energy is a mother of all forms of energy: conventional or non-conventional, renewable or non-renewable, the only exception being nuclear energy. The Sun subtends an angle of 32' at the earth's surface. India lies between 7° and 37° N and receives an annual average intensity of solar radiation between 16,700-29,260 kJ/sq.m per day that is 400-700 Cal/sq.cm per day. Peak values in April or May with parts of Rajasthan and Gujarat is 25,100 kJ/sq.m per day and 16,700 kJ/sq.m per day in monsoon and winter seasons. Daily diffused radiation received by whole country is 7,300 kJ/sq.m per day that is 175 Cal/sq.cm per day. Solar power where sun hits atmosphere is 1017 watts and the total demand is 1013 watts. Therefore the sun gives us thousand times more power than we need. If we can use 5% of this energy, it will be 50 times what the world will require. Solar technologies are broadly characterized depending on the way they capture, convert and distribute sunlight.

II. NEED OF THE SYSTEM

Energy is an important input to all sectors of any country. The energy requirement increases rapidly with the increase in population and increase of standard of living. Presently conventional energy sources such as fossil fuels and coal are being used extensively for power generation. But these sources of energy are depleting and may be exhausted by the end of the century or beginning of the next century. As a result most countries have started to explore and experiment the possibility of using non-conventional energy sources such as solar energy, wind energy, water energy and nuclear energy etc. in large scale. The basic problem associated with the conversion

of the solar energy into useful form is that the solar modules used are stationery, so during the morning and evening hours the sun rays fall at an angle upon the module. This decreases the efficiency of the system as the duration of light falling perpendicular to the module is very less. Thus the conversion efficiency of the solar energy into useful form is not up to the mark.

III. OBJECTIVE

The objective of our project is to increase the efficiency of the system by using solar tracking mechanism. This mechanism will ensure that the light with maximum intensity will be falling on the solar panel throughout the day. By means of our system we can gather maximum solar energy and that energy are used to get the electricity.

IV. LITERATURE REVIEW

"Concept of Mechanical Solar Tracking System"; Rohit Agarwal, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), e-ISSN: 2278-1684, p-ISSN: 2320-334X, PP 24-27.

A solar tracking mechanism is an effort to increase the efficiency of power generation through the solar module. The conventional solar module are stationary hence the sun rays falling on them are at different angles at different points of time and the duration of the sun rays falling perpendicular to the surface of the solar module is very small. Please refer to Fig. Thus large part of energy from sun is wasted. This decrease the efficiency of the system as the maximum efficiency is obtain only during the time when sun is exactly perpendicular to the surface of solar module. During the morning and evening hours the efficiency of the solar module is as low as negligible. Those factors lead to problem of very low output by system.[1]

The output of the system can be efficiently increase by the solar tracking mechanism. By the use of this mechanism we can rotate the module according to the movement of the sun is that the sun rays fall exactly perpendicular to the module throughout the day. This increases the power generation by the photovoltaic solar cells in the module, thereby increasing the efficiency.

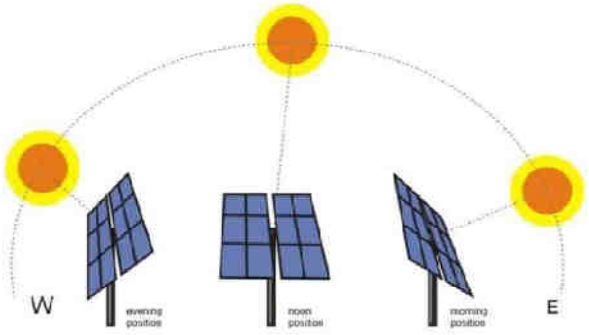

Fig. 1: Tracking of sun path [1]

To achieve this, gear & motor mechanism is used which rotates with a speed is compatible to the speed of movement of the sun. The time duration between the sunrise and sunset is approximately 12 hours and in this duration the sun cove₹ an approximate angle of 180°. So the speed of rotation of the gear mechanism is to adjust that it covers 180° in 12 hour and returns by manually. The solar module is mounted on the solar panels so that it can rotate with the gear mechanism, thereby tracking the path of the sun. Thus the sun rays fall exactly perpendicular to the surface of solar module throughout the day and hence efficiency of power generation by the solar photovoltaic cell in the solar module is increase. [1]

V. METHODOLOGY

The main purpose of solar tracking is to increase the efficiency of the solar system to produce more electricity by tracking the panel according to sun so as to fall sun rays perpendicularly on the panels. This is done by rotating panels with angle equal to angle of sun in which it rotates during a day. This angle is approximately found to be equal to 123° in 9 hours.

As to rotate the panels continuously, we have to give continuous electric supply to the motor which will increase consumption of electricity and it is undesirable. So, it was decided to rotate the mechanism just for a single minute after each hour. This was obtained by using the real timer and the mechanism was decided accordingly.

As large amount of reduction is required, it was decided to choose a motor having low rpm and reduction is obtained through gears and belt drive. So, by this mechanism reduction equal to 2000 was achieved and output speed was found to be equal to 0.03 rpm.

5.1 Experiment to determine angles:

To determine the angles that the panel had to rotate every hour, we carried out an experiment. We took a plain white paper sheet and placed a pointer vertically at the bottom centre of the sheet. We placed the setup on the terrace where sunlight was available for whole day without any shadow falling on the setup. The setup was kept in east-west direction. The shadow of the pointer at 0800hrs was taken as reference pointer and the setup was rotated so as to make the pointer shadow horizontal i.e. pointing to the west direction.

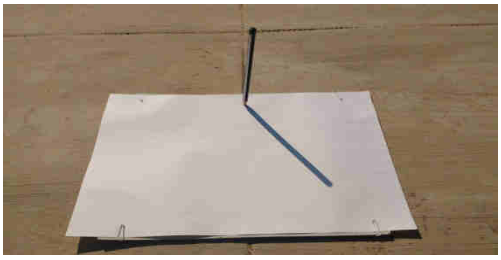

Fig. 2: Setup to measure the angles

After each hour the shadow of the pointer was marked and the angles calculated.

The following experiment was carried out 4-5 times at different places on different as well as same days. Sometimes the experiment had to be stopped due to bad weather like cloudy climate or small showers of rain. After a number of trails, we selected the optimum results.

The angles are as follows:

Table 1. Calculated Sun Angles

Time	Angle
0800 – 0900	6°
0900 – 1000	8°
1000 – 1100	13°
1100 – 1200	19°
1200 – 1300	22°
1300 – 1400	20°
1400 – 1500	17.5°
1500 – 1600	10°
1600 – 1700	7.5°
Total = 9 hrs.	123°

VI. COMPONENTS USED

6.1 AC Synchronous motor:

6.1.1 Motor Specifications:

- Motor speed – 60 rpm
- xTorque – 10 Kg-cm
- Frequency – 50 Hz
- Current – 200 ma
- Voltage – 12 v

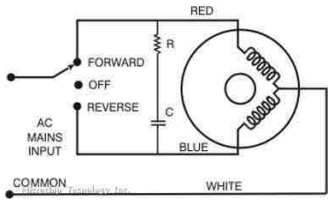

Fig. 3: Motor circuit

6.2 Real Timer:

- 8 channel timer.
- Works with real time clock.
- Least count of 1min

Fig. 4: Real timer

6.3 Gearbox:

Premium Transmission Ltd. Pune

- Worm and worm-wheel Gearbox.
- Reduction of 60:1.

Fig. 5: Worm gearbox

6.4 Solar panel:

- Photovoltaic Polycrystalline solar modules.
- 900×675×35mm
- Max power = 75.0W
  Open ckt volt = 21.72V
  Short-ckt current = 4.60A
  Max power voltage = 17.34V
  Max power current = 4.33A
  Max system voltage = 1000V DC
  Max reverse current = 10A

Fig. 6: Solar panel

Fig.7:Photograph of Assembly of Mechanical Solar Tracking System

VII. COST ANALYSIS

- Cost of purchased parts: ₹ 28526/-
- Cost of manufactured parts: ₹ 5020/-
- Total cost of project: ₹ 33827/-

VIII. RESULTS AND DISCUSSION

8.1 Solar panels stationary and no load attached:

This experiment was done so as to determine the similarity between the two panels. Even though both the Solar panels are of same capacity i.e. 75W and have same specifications but still every solar panel has a different efficiency and therefore we conducted this experiment to determine how identical both the panels are.

8.1.1 Experimental procedure:

i. Mounted the Solar panels on the tracking system.
ii. Placed system such that the panels faced the southeast (SE) direction.
iii. Tilted the panels at 17.85^0 to the horizontal.
iv. Took voltage readings after each hour and noted them down.

The readings obtained where as follows:

Table 2. Readings of Experiment 1

Time	Panel 1 Voltage (V)	Panel 2 Voltage (V)
1000	19.18	19.33
1030	18.86	18.84
1100	18.62	18.60
1130	18.00	18.00
1200	18.48	18.50
1230	18.36	18.40
1300	18.29	18.38
1330	18.57	18.66
1400	18.34	18.43
1430	18.41	18.45
1500	18.44	18.51
1530	18.77	18.77
1600	18.91	18.89
1630	18.70	18.74
1700	18.23	18.04
1730	18.17	18.18
Avg Voltage	**18.520**	**18.545**

From the above results we concluded that the panels are identical.

8.2 One panel static, other panel tracking automatically with timer on/off functions:

In this experiment we kept one solar panel static facing SE at 17.85^0 inclination with the ground level and the other panel was tracking the sun automatically according to the timer. We attached a load which was a 12V battery to the panels and the readings of current and voltage were taken at intervals of 30mins on both the panels.

This experiment is important as the tracking panel was connected to the timer-contactor circuit and was tracking the sun as we had designed and also because it gives an idea about the increase in efficiency of the electricity generation due to tracking of the sun by the solar panel.

8.2.2 Experimental procedure:

i. Placed one solar panel at an angle of 17.85^0 with the horizontal and facing SE.
ii. Placed the other solar panel on the tracking system and rotate the panel to one side such that the panel faces east and the setup is in east-west direction.
iii. Attached the load (12V DC battery) to the panels.
Note: Battery was discharged before connecting to the solar panels.
iv. Readings for current and voltage were noted down after 30mins interval from 0830hrs to 1830hrs.

The readings obtained are tabulated as below:

Table 3. Power readings of panels

Time	Stationary			Tracking		
	Voltage(V)	Current(I)	V×I (W)	Voltage(V)	Current(I)	V×I (W)
0830	12.70	02.16	27.432	12.60	02.60	32.760
0900	12.60	01.90	23.940	12.70	02.72	34.544
0930	12.86	02.94	37.808	12.93	03.03	39.177
1000	12.70	02.40	30.480	12.80	03.56	45.568
1030	12.80	03.47	44.416	12.90	03.62	46.698
1100	12.90	03.62	46.698	12.90	03.63	46.827
1130	13.00	03.67	47.710	13.00	03.57	46.410

1200	13.00	03.80	49.400	13.10	03.63	47.553
1230	13.30	03.96	52.668	13.60	04.30	58.480
1300	13.70	03.42	46.854	13.60	03.48	47.328
1400	13.80	03.31	45.678	14.00	03.52	49.280
1430	13.70	03.30	45.210	14.13	03.53	49.878
1500	13.80	02.67	28.842	14.00	02.60	36.400
1530	13.82	02.09	28.883	14.24	03.34	47.561
1600	13.66	01.57	21.446	14.22	03.14	44.650
1630	13.62	01.07	14.573	14.17	02.82	40.667
1700	13.50	00.71	09.585	13.70	01.25	17.125
1730	13.50	00.34	04.590	14.00	01.98	27.720
1800	13.40	00.29	03.886	13.80	01.14	15.732
1830	13.30	00.07	00.931	13.30	00.19	02.527

Total power obtained in a day (watts):

1. By stationary panel = 576.534 W
2. By tracking system = 740.368 W

Average = (32.760+39.177+46.698+46.410+58.480+47.328+49.878 +47.561+40.667+27.720+2.257)/10hrs

= 43.89 W/hr

= 0.0438 KW/hr

Increase in efficiency = 28.41%

This mechanism can be used for domestic purpose which is beneficial for the household purposes as it can be used in parallel to domestic electric grid and result in less electrical consumption and hence reduced electricity bill.

IX. CONCLUSION

9.1 Advantages:

- Increase in efficiency by about 10%.
- Economical as compared to other solar tracking systems.
- Ideal for domestic installations as well as commercial use.
- Renewable energy source.
- Pollution free.
- Automatic system with no human interference.
- Same mechanism can be used for other systems as well.
- No complex electronic circuits.

9.2 Limitations:

- More increase in efficiency if more channelled real timer is available or the least count of the timer is less.
- Increase in efficiency is not too high.
- Max efficiency of the solar panel is 14.98%.
- Less electricity generation in more clouded environment.

9.3 Efficiency:

- The benefit of this system is to improve the efficiency of the tracking system against the conventional stationary solar panel system.
- The increase in efficiency using our mechanical tracking system is 28.41% which is for summer days as the irradiation is more, it would reduce in monsoon and winter season as the light intensity reaching the earth is less.

X. FUTURE SCOPE

- As the demand of non-conventional energy resources are increasing the total share of solar power in the field of non-conventional energy resources are also in increasing order which somehow create the absolute demand of reliable, sustainable, economic, relatively simple solar sun tracking mechanism. The mechanical solar tracker could provide a solution to solar sun tracking mechanisms because of its design and reliability. Also its energy efficient design and non-programmed operation give lot of advantages. In the future, by utilizing the scientific advancement and research the relative hurdles could be easily rectified and after some more amendment in the future it can be one of the most economically viable solar sun tracking mechanism.
- Instead of single axis tracking system, dual axis system can be used to improve efficiency of the system. This will be more beneficial for seasonal changes.
- The same mechanism can be used for other solar applications such as parabolic reflectors for steam generation, flat plate collectors for water heating etc.
- If used for industrial purposes this setup can be proved to be more economical as the torque produced by the motor is more and more number of panels can be attached.
- By using a real timer having more number of channels or using more number of timers in series

can make the system more accurate and precise. Also using a PLC can serve the purpose but it would be a bit expensive.

- The effects of weather patterns directly impact on the power source to drive the solar tracking and power generation subsystems. Forecasting solar radiation, cloud cover and rain from light intensity will help to improve on board energy management.

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