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Design and Fabrication of a Two Axis Parabolic Solar Dish Collector

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Abstract-
The work consists of the design of the chain drive system and the fabrication of the two axis parabolic solar dish. It is a model study of the two axis parabolic dish which worked by the automatic circuit that was developed. Ready made parabolic solar dish is taken and fabricated. The circular iron ring provides the two axis motion of the dish. A compound chain drive system was developed for the smooth movement of the dish. An electromechanical system which tracks the sun on both axes and which is controlled via a programmable logic control (PLC) was designed and implemented. In this a theoretical study was done. A C program was made which gave the required result for the graphical representation of the recorded radiation. Programmable Logic Controls (PLC) was used instead of photo sensors, which are widely used for tracking the sun. The azimuthal angle of the sun from sunrise to sunset times was calculated for each day of the year at 23.59 Lat & 72.38Longitude in the Northern hemisphere, the location of the city Mehsana. According to this azimuth angle, the required analog signal was taken from the PLC analog module and sent to the power window motor, which controlled the position of the panel to ensure that the rays fall vertically on the panel. After the mechanical control of the system was started, the performance measurements of the solar panel were carried out. The values obtained from the measurements were compared and the necessary evaluations were conducted.

I. Introduction

Even in today's world market, with all of the vast technology advancements and improvements, there are still people who live in darkness at night and use candle light or kerosene lamps to study. These people have the knowledge that electricity exists. However, the area in which they reside lacks the infrastructure and resources for such an amenity. Also, throughout the world, the demand for useable energy is increasing rapidly, with electricity being the energy of choice. This electricity production, however, does not come free. There is cost associated with the infrastructure for setting up new power production facilities and the rising cost and lack of natural resources such as oil, coal, and natural gas. One solution is to steer away from conventional methods and look for novel, alternative, renewable, energy resources, such as solar energy

The main aim of this work is to represent a model study along with the design and fabrication work of the two axis parabolic solar dish. The design of the whole chain drive system is done systematically; right from the sprocket wheels till the length of the chain. This work also aims at the fabrication of the solar dish at economical cost. The fabrication was to be done such that the solar dish would be able to rotate in two axes i.e. east-west and north-south. The automatic circuit is to be designed so that the solar dish could move in the accordance with the movement of the sun. A C program is to be developed such that when we input a location of any city in degrees and minutes, we get the output in a table such that it shows the various radiations received hourly in that place for the whole day. Another C program was to be developed to fit it in the micro-controller to control the movement of the solar tracker according to the movement of the sun, throughout the whole day.

II Experimental Work

a. Selection of the chain Best drives are determined by the factors: life expectance, space, speed and cost. The choice of drive depends on the pitch, number of chains. and sprockets size.

The following factors should be analyzed while selecting a satisfactory chain drive.

1) Type of chain: for low medium speeds roller chains are recommended. Drive ratios greater than 7:1 are not recommended for roller chains. For greater speed ratios it is desirable to compound two or more drives. The chain velocity for roller chains can be as high as 20m/s. however unless the chain is properly lubricated, the normal chain velocities range from 2.5 to 7.5 m/s

2) Basic parameters and kinematics: The main parameter of any chain drive is the pitch. Pitch values have been approximately standardized. The load carrying capacity of any chain drive increases with

increasing pitch which however should be kept within reasonable limits

Figure 1: Fabricated Parabolic Dish

3) Number of teeth in the sprockets: if the number of teeth in the sprockets is very small, i.e. the pitch is very large; it affects badly the chain service life and leads to excessive noise and heavy impact. The maximum no. of teeth is limited by the allowable chain stretch.

a) Minimum number of teeth: Where the mass and size of chain drives are critical, the minimum number of teeth on the smaller sprocket is taken as z_{min} = 13. Most commonly z_{min} in roller-chain drives is found by the following relationship:

z_{1min}=29–2*V

It may be increased to z_{min} = 13 to 15 for V<2 m/s and z_1 = 19 for V>2 m/s

b) Maximum number of teeth: The design of teeth on the larger sprocket is dependent upon the velocity ratio,

$VR=w_1/w_2=z_2/z_1$

•**Chordal Action:** when a chain passes over a sprocket, it moves as a series of chords instead of a continous arc as in the case of a belt drive. Thus the center line of a chain is not uniform radius. This action of chain is shown in fig below.

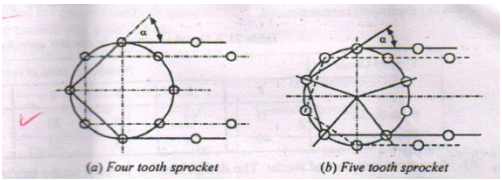

Figure2: Chordal Action of Chain Drive

When the driving sprocket moves at a constant speed, the driven sprocket rotates at a varying speed due to the continually varying radius of chain line. This variation in speed ranges from,

$V_{min} = 2\pi n_1 R \cos(180/z_1)$ to $V_{min} = 2\pi n_1 R$

Where,

R = pitch radius of sprocket

n_1= speed of driving sprocket, rev/min

z_1 = no. of teeth on driving sprocket

It is clear from above that for the same pitch, the variation decreases, if the number of teeth in sprocket is increased. It is also clear from the figure that the angle α known as angle of articulation decreases as the numbers of sprocket teeth are increased. Since the rate of wear of the chain pins and bushings is proportional to the angle of articulation, the greater number of sprocket teeth will result in less wear and longer life of tie chain. It is recommended that for smoother operation, and longer chain life, the pinion should have 21 or more teeth. it is found that if the number of teeth is 25 or more, the chordal action becomes negligible.

The average speed of the chain sprocket is given by

V=pnz/(60*1000)m/s

Where p = pitch of the chain, mm

Velocity ratio is given: $VR = z_2/z_1 = n_1/n_2 = w_1/w_2$

n_1 z_1 = speed and teeth on smaller sprocket, and

n_2 z_2 = speed and teeth on larger sprocket.

(**b) Chain Pitch:** It is the basic dimension of the chain. The selection of the pitch depends on: power to be transmitted, chain speed, number of revolutions of the smaller chain wheel. Its value is given by following formulas:

When the centre distance is known, then

p=C/30to60

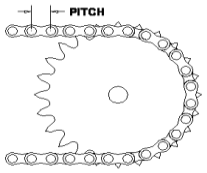

Figure3: Pitch of Roller Chain

(3) Wheel Centres and Length of Chain: The minimum centre distance is selected so as to obtain an adequate angle of wrap on the smaller sprocket for a given velocity ratio. A large angle of wrap or arc of contact assures a more uniform distribution of load on the sprocket teeth and better conditions of engagement. An angle of 90° is regarded as an absolute necessity and 120° is considered desirable.It is evident that to avoid interference. The minimum centre distance is given as

C_{min} = C+(30 to 50mm)for VR

= 1.2C', for VR= 3 to 4

Where $C' = D_{a1} + D_{a2} / 2$

D_{a1} = Addendum, outer or tip diameter of sprocket pinion

D_{a2} = Addendum, outer or tip diameter of sprocket wheel.

Tip diameter may be taken as,

Tip diameter = Pitch diameter + 0.8 * Roller diameter

= Pitch diameter + 0.6* pitch

3.14 Sprockets

A sprocket is a toothed wheel upon which a chain rides. Contrary to popular opinion, a sprocket is not a gear**.** The sprockets used here for our design are taken from the bicycle chain drive system, and bigger socket consists of 48 teeth. And the smaller sprocket consists of 18 teeth. Since the motor used here is of 60 rpm, in order to slow down the speed of rotation of the dish, I have used two pairs of each sprocket. Sprockets should be as large as possible given the application. The larger a sprocket is, the less the working load for a given amount of transmitted power, allowing the use of a smaller-pitch chain. However, chain speeds should be kept less than 1200 feet per minute. The dimensions of a sprocket can also,

Figure 4: Smaller sprocket

Calculated as follows, where P is the pitch of the chain, and N is the number of teeth on the sprocket;
Pitch Diameter = P ÷ sin (180° ÷ N)
Outside Diameter = P × (0.6 + cot (180° ÷ N))
Sprocket thickness = 0.93 × Roller Width - 0.006
Sprockets should be accurately aligned in a common vertical plane, with their axes parallel. Chain should be kept clean and well lubricated with thin, light-bodied oil that will penetrate the small clearances between pins and bushings. Center distance should not be less than 1.5 times the diameter of the larger sprocket, nor less than 30 times the chain pitch, and should not exceed 60 times the chain pitch.

Figure 5: Larger sprocket

Center distance should be adjustable. One chain pitch is sufficient and failing this an idler sprocket should be used to adjust tension. A little slack is desirable, preferably on the bottom side of the drive. The chain should wrap at least 120° around the drive sprocket, which requires a ratio of not more than 3.5 to 1; for greater ratios, an idler sprocket may be required to increase wrap angle.

3.24 Cost analysis

The parabolic dish was provided from the college. The fabrication was done at the chaudhary fabricators, Ahmedabad, which includes an iron stand and a circular ring along with the bicycle sprockets connected to a power windows motor by means of chain. the total cost of fabrication was RS 5000.the tracking circuit cost RS 1300.

3.25 Reasons for using such a drive system

As we know that the motor used here has a speed of 60 rpm, which is not suitable for the tracking system, in order to reduce the speed of the system, a compound drive system is used. By using such a type of chain drive system, a desired speed can be easily obtained and controlled.

3.27 The tracking mechanism

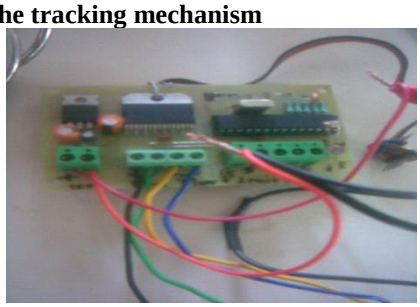

Figure 6: The circuit showing the various components

1. PLC16F876A

The PIC16F876A features 256 bytes of EEPROM data memory, self programming, an ICD, 2 Comparators,5 channels of 10-bit Analog-to-Digital (A/D) converter, to capture/ compare/ PWM functions, the synchronous serial port can be configured as either 3-wire Serial Peripheral Interface (SPI™) or the 2-wire Inter-Integrated Circuit (I²C™) bus and a Universal Asynchronous Receiver Transmitter (USART). All of these features make it ideal for more advanced level A/D applications in automotive, industrial, appliances and consumer application

Figure 7: PLC16F876A

2. Light dependent resistor (LDR)

A photo resistor or light dependent resistor or cadmium sulfide (CdS) cell is a resistor whose resistance decreases with increasing incident light intensity. It can also be referred to as a photoconductor. A photo resistor is made of a high resistance semiconductor. If light falling on the device is of high enough frequency, photons absorbed by the semiconductor give bound electrons enough energy to jump into the conduction band. The resulting free electron (and its whole partner) conduct electricity thereby lowering résistance photoelectric device can be either intrinsic or extrinsic. They are also used in some dynamic compressors together with a small incandescent lamp or light emitting diode to control gain reduction. LDRs or Light Dependent

Resistors are very useful especially in light/dark sensor circuits. Normally the resistance of an LDR is very high, sometimes as high as 1000 000 ohms, but when they are illuminated with light resistance drops dramatically.

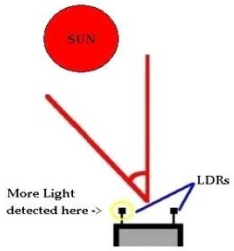

Figure 8: Light dependent resistor

3. L298

The L298 is an integrated monolithic circuit in a 15 lead Multiwatt and PowerSO20 packages. It is a high voltage, high current dual full-bridge driver designed to accept standard TTL logic levels and drive inductive loads such as relays, solenoids, DC and stepping motors. Two enable inputs are provided to enable or disable the device independently of the input signals. The emitters of the lower transistors of each bridge are connected together and the corresponding external terminal can be used for the connection of an external sensing resistor. An additional supply input is provided so that the logic works at a lower voltage

Figure 9: L298

4. L7805

The 7805 is a voltage regulator. It looks like a transistor but it is actually an integrated circuit with 3 legs. Turn it into a nice, smooth 5 volts DC. You need to feed it at least 8 volts and no more than 30 volts to do this. It can handle around .5 to .75 amps, but it gets hot. Use a heat sink Run off of 5 volts. It can take a higher, crappy DC voltage and Use it to power circuits than need to use or run off of 5 volts

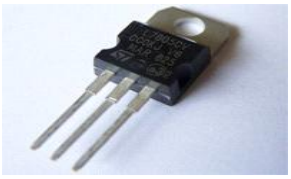

Figure 10: L7805

5. Diodes

In electronics, a diode is a two-terminal electronic component that conducts electric current in only one direction, while blocking current in the opposite direction (the *reverse* direction). Thus, the diode can be thought of as an electronic version of a check valve This unidirectional behavior is called rectification, and is used to convert alternating current to direct current, and to extract modulation from radio signals in radio receivers

6. Resistors

A resistor is a two-terminal passive electronic component which implements electrical resistance as a circuit element. When a voltage V is applied across the terminals of a resistor, a current I will flow through the resistor in direct proportion to that voltage.

Figure 11: Resistor

Conductance is known as the resistance R, since, with a given voltage V, a larger value of R further resists the flow of current I as given by ohm's law: I = V/R

7. Relay

A relay is a simple electromechanical switch made up of an electromagnet and a set of contacts.A relay is used to isolate one electrical circuit from another. It allows a low current control circuit to make or break an electrically isolated high current circuit path

8. 4MHZ Oscillator

crystal oscillator is an electronic oscillator circuit that uses the mechanical resonance of a vibrating crystal of piezoelectric material to create an electrical signal with a very precise frequency. This frequency is commonly used to keep track of time (as in quartz wristwatches), to provide a stable clock signal for digital integrated circuits, and to stabilize frequencies for radio transmitters and receivers.

Figure 12: 4 MHz oscillator

A C program was developed in order to find out the various radiations that occur. The calculations were made on 15 of every month. Recordings were done from morning 7 to evening 6. The program was developed such that when the date and month were input, the beam radiation, diffused radiation and global radiation from 7 a.m to 6 pm would be displaced along with the table.

III Results and discussion

According to the table, city Mehsana is located at

23˚N 35.3 minutes. Taking this information and inputting it in the program the whole set of information of the table can be found. According to the table we have plotted the graphs for different radiations. and the comparison was made, and we found that in the month of May and June, there was maximum radiation at the city Mehsana. Radiation at the peak level was at 12 p.m.

Theoretical recordings were made on the various radiations which were received at the city Mehsana. Each month radiations (i.e. global, diffused, beam radiation) were theoretically recorded. From morning 7 a.m.to 6 p.m.and it was found that the radiation was highest at the noon time.i.e at 1.00 p.m. and least at the early morning and late evening time. From the monthly recorded radiations, the average was taken from each month and a new graph was plotted.

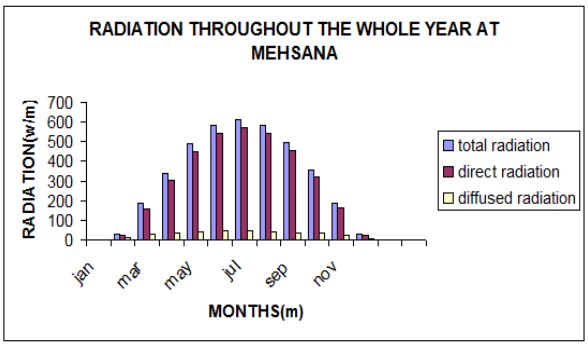

Fig: Average Solar Radiation of city Mehsana at 23.59 Lat & 72.38Longitude

The x-axis was plotted as the 12 months of the year. And the y-axis was plotted as the various average recorded radiations. This graph shows that among the various radiations which were recorded; it was observed that during the month of May and June there is basically the maximum amount of solar radiation received by earth.

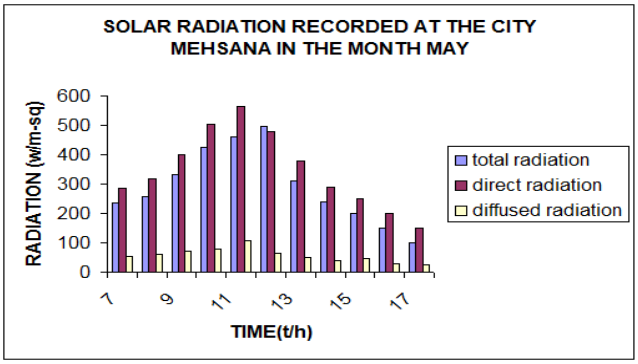

Figure 3.2: Maximum Solar Radiation at Mehsana in May

Another graph was plotted separately for the month of June. The x-axis shows the time.i.e 7.00 am to 6.00 pm. according to the graph, it was clear that the diffused radiation was of very small content but it cannot be clearly neglected during the calculation. The radiation on earth is received in two forms. Beam and diffused forms. On adding the two we get the global or the total radiation. it was recorded that during the morning time the radiation is not very high. But as the time passes and the peak radiation time i.e. afternoon time is reached, it is found that the radiation at this time is the maximum. Again as the time passes toward the evening the radiation amount goes on decreasing and at the evening time it is recorded minimum.

From the above graphical representation, it is clear that maximum amount of solar energy can be stored during the month of June. if our work is fully dependent on solar energy, the summer time is the best.

The solar parabolic dish at the morning is facing the sun, which also rises from the east. Now the movement of sun will be followed by our dish. As the sun moves every second, the dish follows its motion. The motion of dish is controlled by the automatic circuit. When the sun reaches the noon time the dish is also straight facing the sun horizontally as well as vertically. Now when the sun starts its movement from the afternoon time to the evening time, the dish also rotates itself according to the sun's movement. When the sun sets, the dish has also reached its west position.

The circuit has the ability to move the dish such a way that when the sun rises, the dish also has moved automatically to the east position. When the sun rises, the same process is followed again and the radiations are recorded.

IV Conclusion

From the theoretical recordings, taken throughout the year, it was clear that the average solar radiation was maximum at the month of May and June. From the above recording we conclude that

- The summer season is the best to store the solar energy. We can also see that when the sun rises the solar dish is also in the east position facing the sun on sideways. But as the time passes and reaches the afternoon time, it was seen that the dish faced fully towards the sun.
- When the sun is overhead at 12pm and 1pm, the dish deflects maximum from its original position. And the solar radiation recorded during the afternoon time is the maximum as compared to the other hours. In the evening time when the sun sets at east the dish is also in the west zone.
- The dish automatically comes back to the east position by the time the sun rises. This happens due to the automatic tracking circuit that we have developed.
- The chain drive so developed, minimizes the jerks given by the 60 rpm power window motor. So that the system works in a smoother way.
- When the battery was directly connected to the circuit relay, the whole circuit was

damaged. So to avoid the direct supply of current from battery to the circuit, a 12 volt ammeter was used. The use of ammeter made the working smoother without any damage.

- If a 2 or 3 rpm geared motor will be used, the system will work more smoothly.
- If a reduction gear box was to be used instead of the system I used, there would be a better movement of the dish. A jerk free movement will be provided.
- The automatic tracking device so developed also worked efficiently in all conditions.

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