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A review on Design and construction of a one-axis sun-tracking system

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Abstract - *This paper explains a tracking system which can be used with single-axis solar concentrating systems. The position and "status" of the Sun are detected by three light-dependent resistors (LDRs), one of which detects whether the collector is focused, whilst a second resistor determines if there is cloud cover, and the third senses whether it is day or night. The resultant signals are passed to an electronic control system which operates a low-speed 12-V d.c. motor which rotates the collector with the help of a speed-reduction gearbox. The tracking system accuracy depends on the magnitude of the solar radiation. The deviation from zero is 0.3 and 0.06 ° with solar radiation of 95and 550 W m-2, respectively. Both values instruct that the mechanism can be used comfortably for parabolic trough collectors of medium to high concentration ratios.*

Key Words: tracking, solar radiation, concentrating ratio, etc

Introduction

Concentrating solar collectors can provide considerable advantages over the usual flat plate collectors especially for medium- to high-temperature applications, although the Sun must be very accurately tracked to ensure good thermal performance. Various forms of tracking mechanisms, varying from complex to very simple, have been proposed. They can be divided into two broad categories, namely mechanical and electrical/electronic systems. The electronic systems generally exhibit improved reliability and tracking precision. These can be further subdivided into:

(1) Mechanisms employing motors controlled electronically through sensors which detect the magnitude of the solar illumination

(2) Mechanisms using computer-controlled motors with feedback control provided from sensors measuring the solar flux on the receiver

Although these latter systems employing computer control are more costly. Due to the fact that the Sun always moves in single direction, it is believed that the refinement of the feedback control does not justify the supplementary cost.

The Tracking System

A tracking mechanism must be reliable and capable to follow the Sun with a some degree of accuracy, return the collector to its original position at the end of the day or during the night, and also track during periods of intermittent cloud cover. The required accuracy of the tracking mechanism depends on the collector acceptance angle. This angle is defined as the range of solar incidence angles, measured relative to the normal to the tracking axis, over which the efficiency varies by less than 3% from that associated with normal incidence (ASHRAE, 1987). The results of tests, carried out on the parabolic trough collector model constructed as part of a research work , are presented in Fig. 1.

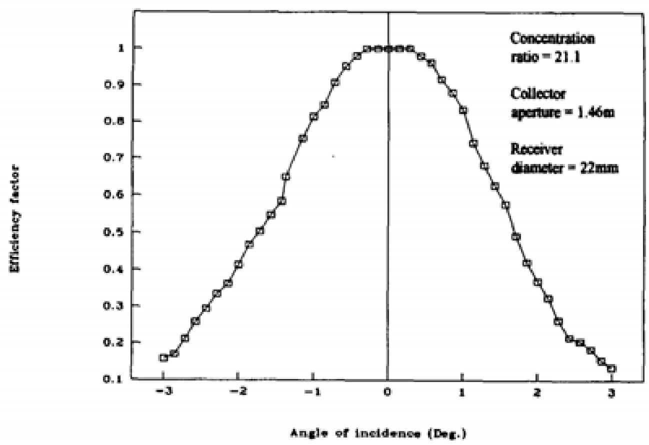

Fig 1: Collector acceptance angle.

The acceptance angle of this collector is approximately 1.6 ° (Kalogirou, 1994). It thus appears that it is sufficient for the present mechanism to track the Sun with an accuracy of 0.7 ° (The employed mode of tracking is the E-W horizontal, i.e., the parabolic trough collector axis is orientated in a N-S direction and the collector tracks the Sun in an E-W direction and styled.

System Description

The final system, which was designed to operate with the required tracking accuracy, consists of a small direct current (d.c.) motor which rotates the collector via a speed-reduction gearbox. A control system is used to detect the Sun's position and operate the motor.

A diagram of the system, to gather with a table showing the functions of the control system, are presented in Fig. 2. The system employs three sensors of which A is installed on the east side of the collector shaded by the frame, whereas the other two (B and C) are installed on the collector frame. Sensor A acts as the "focus" sensor, i.e., it will only receive direct sunlight.

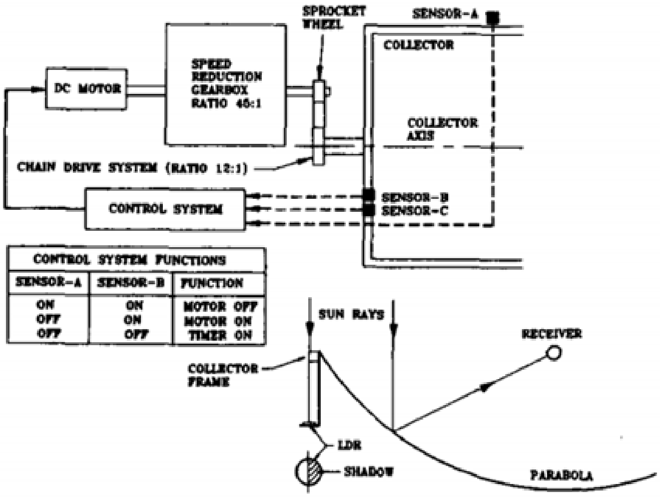

Fig 2. Tracking mechanism-system diagram.

when the collector is focused. As the Sun moves, sensor A becomes shaded and the motor turns "ON". Sensor B is the "cloud" sensor and cloud cover is assumed when illumination falls below a certain level. Sensor C is the "daylight" sensor. The condition when all three sensors approach sunlight is translated via control system as daytime with no cloud passing over the Sun and the collector being in a absolutely focused position. The functions shown in the table of Fig. 2 are followed provided that sensor C is "ON", i.e., it is daytime.

The control system

When the preliminary stages of the design of the control system a number of sensor types were considered including photocells, bimetallic strips, fluid-mechanical devices and light dependent resistors (LDRs).

These all have few merits, e.g., the performance of sensors which depend upon heat differences are affected by other ambient conditions such as wind and temperature. Photocells were rejected because they require a large area in order to supply the power required for the operation of the relays.

The principle of operation of the system is demonstrated in the control diagram presented in Fig. 3. The present LDRs are type ORP 13 (RS, 1991). Their resistances normally 310Ω in the shade and15 Ω in direct sunlight.

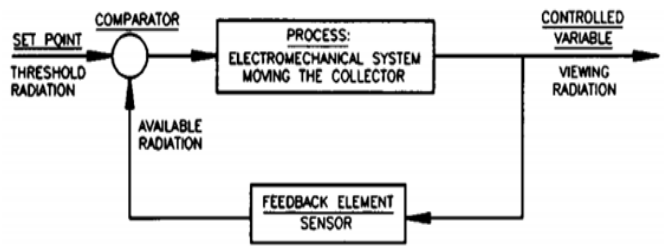

Fig 3. Tracking mechanism- control diagram

As mentioned previously, the motor of the system is switched on when any of the three LDRs is shaded. Which sensor is activated depends on the amount of shading determined by the value set on the adjustable resistor, i.e., threshold value of radiation required to trigger the relays. The logic with which each sensor behaves is shown by the flow charts presented in Fig. 4 Irjet template sample paragraph, Irjet template sample paragraph .Irjet template sample paragraph. Irjet template sample paragraph

Sensor A is always partially shaded. As the shading increases, due to the movement of the Sun, a value is reached which triggers the forward relay which switches the motor on (connection not shown in Fig. 5), to turn the collector and therefore re-exposes sensor A.

The system also accommodates cloud cover, i.e., when sensor B is not receiving direct sunlight, determined by the value of another adjustable resistor, a timer is automatically connected to the system and this powers the motor every 2 min for about 8s (see Fig. 4). As a result the collector usually follows the Sun's path, and when the Sun reappears the collector is re-focused by the function of sensor A

The system also incorporates two limit switches, the function of which is to stop the motor from going beyond the rotational limits. These are installed on two stops, which restrict the overall rotation of the collector in both directions, east and west. The collector tracks to the west as long as it is daytime. When the Sun goes down and sensor C determines that it is night, power is connected to a reverse relay (see Fig. 4) which changes the motor's polarity and rotates the collector until its motion is restricted by the east limit switch. If there is no Sun during the following morning, the timer is used to follow the Sun's path as under normal cloudy conditions. Figure 5 is a block diagram of the control system showing the three sensors together with the timer chip, forward and reverse relays, and limit switches (denoted as east and west L/S). The control system uses a combination of inverters and "nand" gates in order to "translate" the resistance of the LDRs into a signal which triggers the relays. Nand gates give a logic high "1" signal when any of the input signals is logic zero "0." They give logic zero "0" signal when all input signals are logic high "1". Light-emitting diodes (LEDs) are employed to show the condition of the sensors and motor.

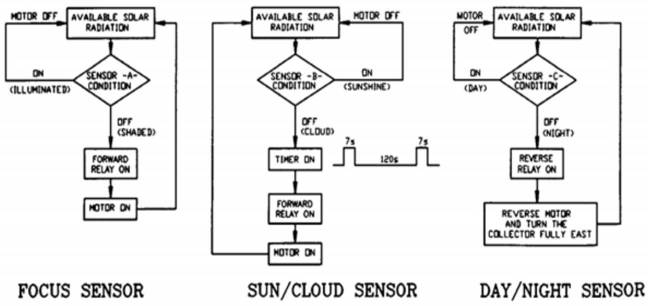

Fig 4. Sensor function flow charts.

Performance of the tracking Mechanism

The Sun "travels" at a constant speed of 0.27 ° min -1, so that tracking accuracy (i.e., the out of focus angle required to initialize the system), can be determined by measuring the period between successive operations of the motor.

The tracking mechanism proved to be very Reliable and durable during the testing period of about 3.5 years. All the functions of the control system as described previously performed reliably. The function which allowed the mechanism to follow the approximate path of the Sun when shaded behind a cloud was very effective as less than 25 s were needed to re-focus the collector after the Sun reappeared. Extensive testing of the solar collector established that the tracking mechanism was very effective and accurate. The accuracy of the system depends on the intensity of the Sun's illumination. In the worst case, with radiation of the order of 95 W m -2, the accuracy of the position mechanism was 0.3°.This variation was reduced to 0.05 ° with radiation levels of about 550 W m - 2. Thus the mechanism performed satisfactorily throughout the year in the present parabolic trough collector application. The accuracy was much greater than the suggested 0.7° which was derived by the collector acceptance angle test (Fig, 1). The accuracy of the tracking mechanism can be increased by changing the value of the adjustable resistor connected in series with sensor A.

Conclusion

The electronic tracking mechanism, which was designed and constructed, has proved to be nearly accurate for the present solar energy utilization . The accuracy is such that the mechanism can be used for "tracking" solar parabolic trough collectors of medium to high concentration ratios, under any weather conditions.

The mechanism may also find application in other systems which are required to follow the path of the Sun, e.g., equipment used for measuring solar beam radiation, In this case the pointing error must be smaller than the instrument's angular field of view, which is typically 8°, and the instrument is usually mounted on a platform which tracks the Sun. The accuracy obtained from the proposed tracking mechanism is well within safe limits.

Tracking in the altitude direction could be achieved by manual periodic adjustment. Beam radiation measurement is also required in cloudy conditions so that the ability of the present mechanism to follow the Sun in these conditions is particularly important for computerized data collection.

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