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LINE-FOCUS SUN TRACKERS

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ABSTRACT

Sun trackers have been a troublesome component for line-focus concentrating collector systems. The problems have included poor accuracy, component failures, false locks on clouds, and restricted tracker operating ranges. In response to these tracking difficulties, a variety of improved sun trackers have been developed. A testing program is underway at SERI to determine the tracking accuracy of this new generation of sun trackers. This paper defines the three major types of trackers, describes some recent sun tracker developments, and outlines the testing that is underway.

1. INTRODUCTION

Most single-axis concentrating collectors track the sun to maintain the concentrator focus on the receiver. Many of these systems have been plagued with operational difficulties due to poor sun tracking [1-4]. Recently, several companies have developed improved sun trackers. However, little has been done to quantify tracking performance. An effort is underway at SERI to test sun trackers for tracking performance and to identify the impact of tracking errors on system performance. Preliminary results of this testing will be presented at the conference.

2. TRACKER TYPES

There are three major types of sun trackers: computer trackers, shadow band trackers, and flux line trackers. A computer tracker (Fig. 1) uses a clock input to compute the sun's position and initiates collector rotation to this computed angle. Although quite simple in theory, this type of tracker requires an accurate method of accounting for the collector's angular position as it is rotated. Shaft encoders have often been used. The expense of high-resolution position sensors has been the key problem. Also, the necessity of computing the sun's position requires a computer or microprocessor and its added expense. If low-cost, high-resolution position sensors become available, computer trackers will be more attractive. Also, if several collectors are driven together using just one sun tracker, tracker costs can be lessened significantly.

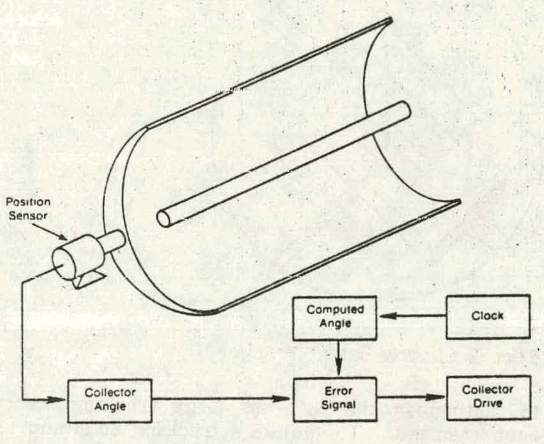

Fig. 1 Computer Tracker

Shadow band sun tracking (Fig. 2) is the most popular method of providing the tracking function. A shadow band sensor is mounted on the collector and rotates with it. Two sensors are separated by a partition or shadowing strip, which shades one of the sensors if the tracker is not pointed directly at the sun. The sensors produce an error signal when both sensors are not equally illuminated. This error signal initiates collector rotation until the sensors are equally illuminated (at which point the collector is correctly aligned). The geometry of the shadowing strip and placement of the sensors varies greatly between manufacturers, but they all rely on generation of an error signal as a result of unequal illumination. Several shadow band trackers have had operational difficulties. Many of the problems were caused by poor quality components and assemblies. However, hazy or cloudy conditions have been troublesome to tracker electronics and have also resulted in poor tracking performance. In some cases, tracker electronics have been "confused" by cloud cover and have tracked clouds rather than the sun. In other installations, the sun sensor outputs vary greatly with variable sky conditions and have led to erratic tracking. On hazy or cloudy days, when direct insolation is decreased and diffuse insolation increased, the sensors of some trackers are not able

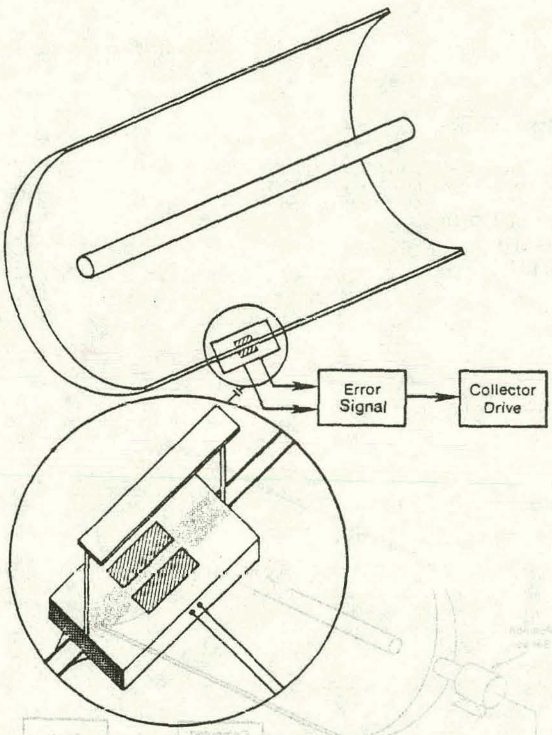

Fig. 2 Shadow-Based Tracker

to distinguish the sun, and large tracking errors have resulted. To maintain tracking accuracy as sky/cloud conditions change, manual adjustment of the sensor sensitivities has often been required.

Flux line trackers (Fig. 3) have sensors located at or near the receiver and are sensitive to concentrated flux. As with shadow band trackers, if the collector is off-pointed, an error signal is generated, and the collector rotates until the error signal is nulled. This tracking concept eliminates the diffuse insolation problems associated with shadow bands because, to a good approximation, only direct insolation is reflected to the receiver. Flux line trackers are the only tracker type that orient the collector based on where the focal line actually is, rather than where it should be. Computer trackers and shadow band trackers rely on a fixed relationship between the focal line and a collector reference point.

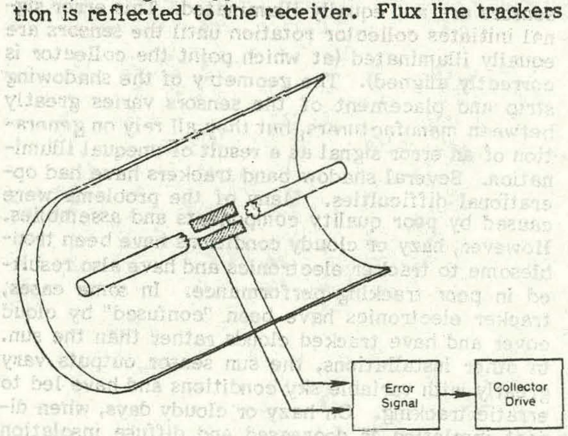

Fig. 3 Flux-Line Tracker

3. RECENT DEVELOPMENTS

Acurex Corporation has recently developed an improved shadow band sun tracker (Fig. 4). The sensors' field of view has been narrowed to eliminate much of the influence of clouds and diffuse sky radiation. Also, the electronics have been altered to automatically compensate for changing insolation levels. Further, Acurex has added an additional element of control—a direct insolation monitor (DIM). Tracking is initiated only when direct insolation exceeds a threshold value. Should a cloud pass the sun, the DIM instructs each collector to hold its position. When the sun reappears and a direct insolation threshold is exceeded, normal tracking continues.

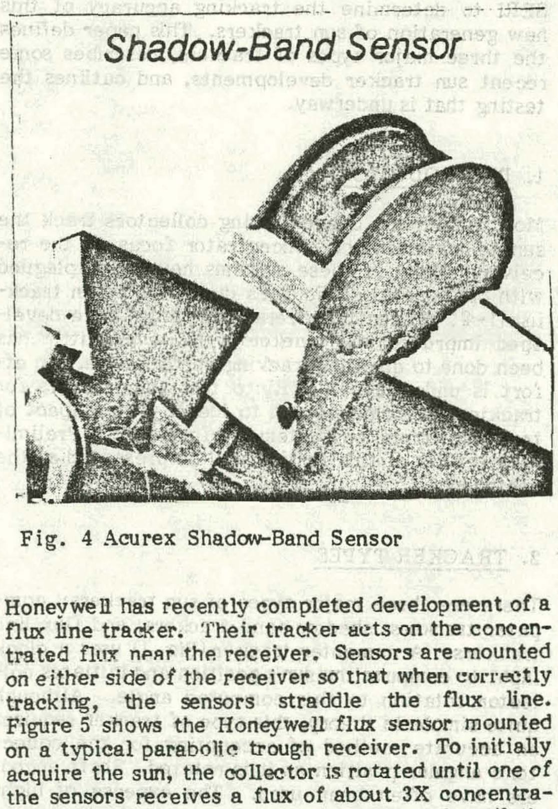

Fig. 4 Acurex Shadow-Band Sensor

Honeywell has recently completed development of a flux line tracker. Their tracker acts on the concentrated flux near the receiver. Sensors are mounted on either side of the receiver so that when correctly tracking, the sensors straddle the flux line. Figure 5 shows the Honeywell flux sensor mounted on a typical parabolic trough receiver. To initially acquire the sun, the collector is rotated until one of the sensors receives a flux of about 3X concentration. The collector is then incremented until the flux beam balances the sensors. If off-pointed, the sensors generate an error signal, and the collector is rotated until the sensor again straddles the flux line.

The Marshall Space Flight Center has developed a shadow band tracker for north-south rotation axis

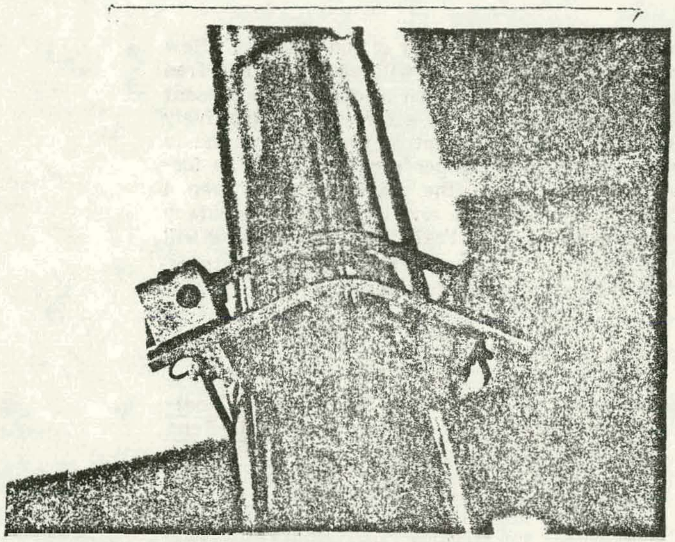

Fig. 5 Honeywell Flux-Line Sensor

collector that reverts to a clock drive when clouds obscure the sun. Figure 6 is a schematic of the shadow band sensor. Silicon cells provide the error signal, which controls collector rotation during normal tracking operation. The field of view of the cells is restricted so that the cells are not subject to sky/cloud conditions away from the sun. When a cloud covers the sun, cell outputs drop and the tracker circuitry is signaled to provide a constant tracking rate of 15 degrees per hour. For north-south rotational axis collectors, this constant drive rate keeps the tracker roughly pointed at the sun, even when cloudy. When the sun reappears, it is within the acquisition angle of the sensor, and the silicon cells resume control.

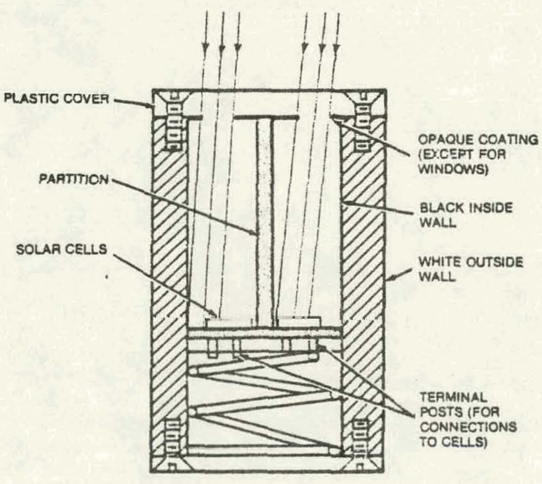

Fig. 6 Marshall Space Flight Ctr. Shadow-Band Sensor

Sandia Laboratories, Albuquerque, have combined a computer tracker and a flux line tracker (Fig. 7). The tracking angle is calculated with a microprocessor, and the collector is positioned to this angle. Fine-tuning of the tracking angle is accomplished with a flux line tracker. A pair of resistance wires, helically wrapped down the receiver, provides an error signal. The resistance wire spans the full length of the receiver and serves to integrate the receiver's entire flux distribution to find the best tracking angle for the collector as a whole.

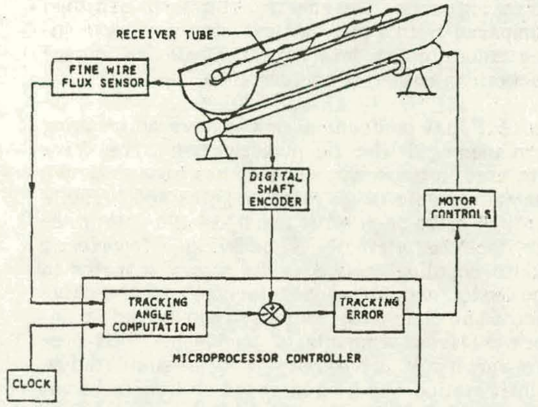

Fig. 7 Sandia Computer/Flux-Line Tracking Schematic

Several other companies are in the process of developing improved sun trackers. These include Alpha Solarco, Del Manufacturing Co., Solar Kinetics, Sunpower Systems, Viking Solar Systems, and Israel's Weizmann Institute of Science.

4. TESTING PROCEDURES AT SERI

The Solar Energy Research Institute is testing the tracking accuracy of sun trackers. Each system of tracker electronics is being installed on a highly controllable hydraulically driven test stand. The tracker electronics control a hydraulic rotary actuator, which provides collector rotation. A precision shaft encoder (resolution beyond 0.05 degrees) generates pointing angle signals to an on-site computer. The shaft encoder provides an accurate account of instantaneous pointing angle as the collector tracks throughout the day. The instantaneous pointing angle is compared with the ideal pointing angle, as calculated by the on-site computer, to determine the instantaneous tracking error. These measurements are taken for several days to ensure repeatable results. Of particular interest is tracking performance for the range of sky/cloud conditions that operating systems encounter. Each sun tracker is tested until its performance as a function of cloud cover, insolation level, and time of day is characterized.

Some sun trackers may track very accurately during high-insolation periods but less accurately under low insolation. However, poor tracking is less significant during low-insolation periods than during high insolation periods because the energy available to the collector is smaller. Therefore, to provide a meaningful measure of tracking performance, tracking accuracy must be weighed by the available insolation. Tracking accuracy may also be impacted by time of day effects such as incidence angles. Once these characteristics have been established, they can be used to calculate a long-term average rms tracking error. The rms tracking error can then be compared with other optical errors of concentrating collectors to determine the relative impact of trackers on collector performance.

The effect that mechanical drives have on tracking performance will also be investigated. The drive system used in these experiments has been designed to permit variable drive rotation rates and variable amounts of drive backlash. The hydraulic rotary actuator itself has virtually no backlash. However, a "backlash coupling" connects the rotary actuator to the collector and introduces backlash to the drive system. The "backlash coupling" can be set to introduce different amounts of backlash. This permits a variety of drive systems to be simulated so that information can be generated on how drive rotation rate and drive system backlash affect tracking performance.

5. CONCLUSION

The tracking performance of line-focus concentrating collectors will certainly improve because of the current development activity in sun trackers. New concepts and improvements will lead to trouble-free and sufficiently accurate sun trackers. The present performance testing is an effort to quantitatively define the state of the art of sun trackers and to identify which concepts perform best. Also, a further understanding of the relationship between a collector's drive system and its tracking accuracy may prove beneficial. Preliminary test results will be presented at the conference, and complete results will be published in late summer [5].

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15. Supplementary Notes

16. Abstract (Limit: 200 words)

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