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Heliostat Dual-Axis Sun Tracking System: A Case Study in KSA

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Abstract

This paper demonstrates a case study for solar power tower (SPT) Heliostat, concentrated solar power topology in Dhahran, KSA. A MATLAB code is implemented for the solar position algorithm to calculate the incident angles in order to track the sunbeams during the whole year. A Dual-axis drive system based on linear actuators is designed and implemented. The proposed Heliostat prototype has been tested at different seasons to confirm the tracking system accuracy. The experimental and simulation results are well agreed. The proposed drive system could perform accurate tracking using cheap feedback sensors and digital controller.

Objectives

- In this work, a solar drive system with dual-axis tracking has been developed and simulated for the site of Dhahran, in the east of KSA.
- A MATLAB code is implemented to simulate solar and Heliostat azimuth and elevation angles for the whole year.
- Arduino microcontroller is interfaced to global position sensor (GPS) to extract the time and location.
- Then, Heliostat angles are calculated in order to move the dual axis drive systems.
- The proper switching pulses are generated to steer the power electronic converter for the accurate movement.

Proposed Tracking System

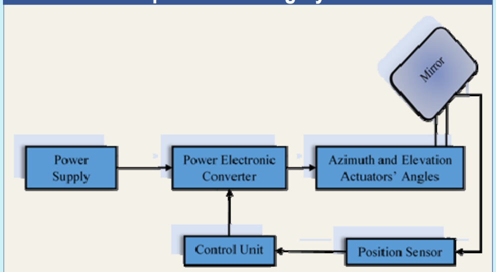


Figure 1

Heliostat tracking Model

$$\sin(\alpha_s) = \cos(\varphi)\cos(\delta)\cos(\omega) + \sin(\varphi)\sin(\delta) \quad (1)$$

$$\gamma_s = \mathrm{sign}(\omega)\left|\cos^{-1}\left(\frac{\cos(\theta_z)\sin(\varphi) - \sin(\delta)}{\sin(\theta_z)\cos(\varphi)}\right)\right| \quad (2)$$

- *Converter the two sun angles to x_1, y_1, & z_1 values*

$$\left.\begin{aligned} z_1 &= \sin(\alpha_S) \\ hyp &= \cos(\alpha_S) \\ x_1 &= hyp * \cos(\gamma_S) * -1) \\ y_1 &= hyp * \sin(\gamma_S * -1) \end{aligned}\right\} \quad (3)$$

- *Converter the two target angles to x_2 , y_2, & z_2 values:*

$$\left.\begin{aligned} z_2 &= \sin(\alpha_T) \\ hyp &= \cos(\alpha_T) \\ x_2 &= hyp * \cos(\gamma_T) * -1) \\ y_2 &= hyp * \sin(\gamma_T * -1) \end{aligned}\right\} \quad (4)$$

- *From both points, x, y, and z are calculated:*

$$\left.\begin{aligned} distance &= \sqrt{x^2 + y^2 + z^2} \\ \alpha_H &= \mathrm{asin}\left(\frac{z}{distance}\right) \\ \gamma_H &= \mathrm{atan2}(y * -1, x) \end{aligned}\right\} \quad (5)$$

Heliostat and Tower Angles used for Tracking

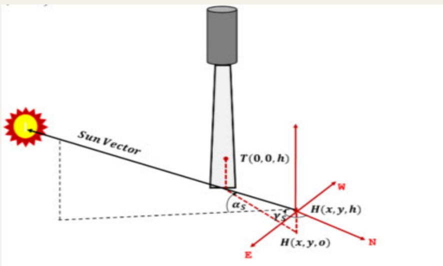


Figure 2

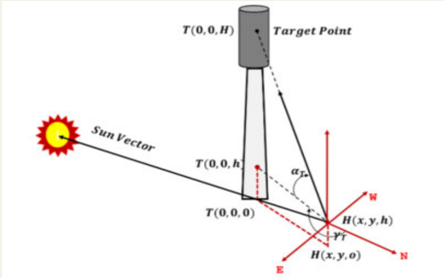


Figure 3

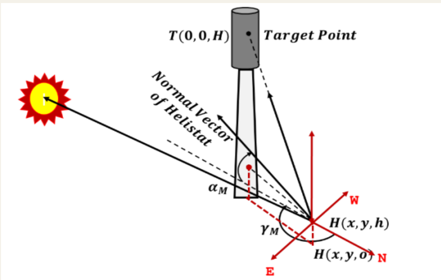
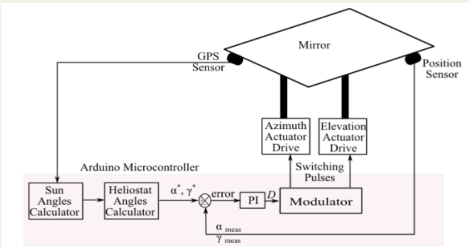
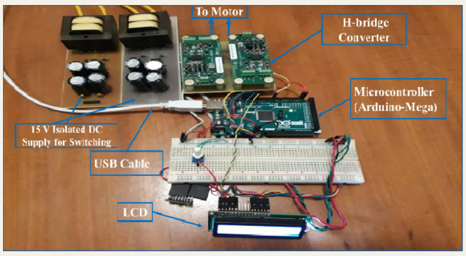


Figure 4

Tracking System Schematic and Experimental Setup



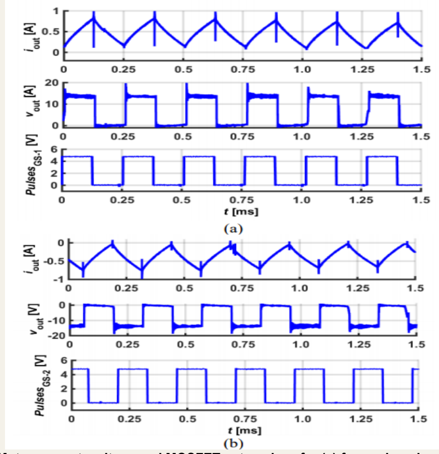
Block diagram of dual-axis solar tracking system



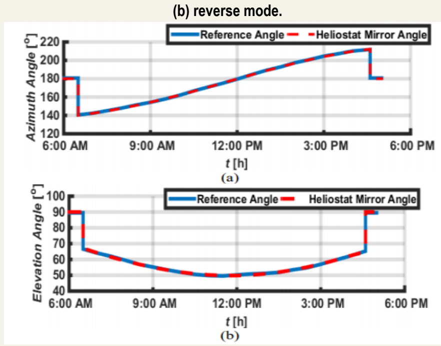
Experimental Setup for Drive System

The proposed Roof-top Heliostat Prototype at KFUPM, KSA.

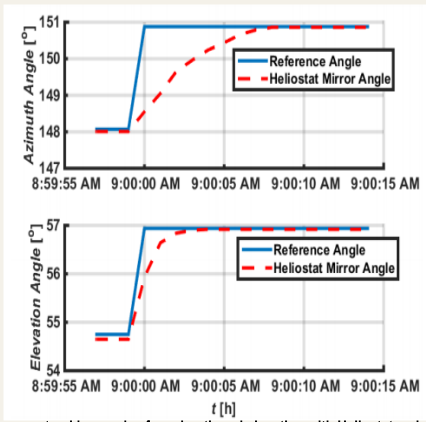
Simulation and Experimental Results



Motor current, voltage and MOSFET gate pulses for (a) forward mode and (b) reverse mode.



(a) Reference and tracking angle for azimuth motion angle. (b) Reference and tracking angle for elevation motion angle with Heliostats mirror angles on 10th . Sep. 2019



Reference tracking angles for azimuth and elevation with Heliostats mirror angles at 09:00 AM

Conclusion

- The work discusses the dual-axis Heliostat solar drive system, apart of a developing renewable energy technology.
- The design includes the use of an advanced SiC-based drive system applied to dual axis linear actuators. A GPS module is used to feed the microcontroller with the current positions to perform the solar tracking.
- The controller could perform the solar tracking accurately and with cheap feedback sensors.
- The experimental and simulation results are in a good agreement.
- The current and future work is to measure the system performance in terms of drive system efficiency and the effect of the KSA harsh weather conditions on the proposed SiC-based Drive system

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