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Simulation regarding solar panel tracking system based on Sun's position

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Abstract. The following article describes a tracking system to keep a solar panel aligned with the Sun. It was designed in Matlab using Simulink. The model consists in a panel, a motor and a controller which is used to track the position of the Sun. The physical system is based of two equations of motion, one for the panel and the other one for the motor. The purpose of building the tracking system is keeping a maximum intensity of producing electricity during all day.

1. Introduction

The article is about developing a tracking system for the Sun's position in order to keep the solar panel aligned with it. The simulation has two equations of motion, one for the panel and one for the motor. The parameters of the simulation are loaded from an Graphical User Interface which was created also in Matlab. Most of the solar panels are orientated in a single direction and it can affect the amount of electricity produced by the panel hence the main purpose of building the tracking system is keeping a maximum intensity of producing energy during all day.[1, 2, 3] If a solar panel is perpendicular to the position of the Sun, more sunlight will strike the panels, less light is reflected and more energy is absorbed.[4]

2. Theoretical foundation of the article

The position of the Sun is determined with complex instruments including computers, which process the algorithms and sensors in order to provide information about the location of the Sun.[5] Also, a simple circuit board can be attached to the solar panel without using a computer. The position of the solar panel is perpendicular to the Sun's position because if the angle is smaller the effect on power output is less effective than a larger angle. Tracking the east to west motion is more important than south to north because Sun's angles changes north to south seasonally and east to west daily.[4, 6]

2.1 Advantages and disadvantages

The main advantage of the solar trackers are increasing the power output with 30-40%, fact that can develop the new markets for solar power. One of the disadvantages of the solar trackers is the shorter warranties and the request of more than one actuators to move the panel which increase installation costs and reduce reliability.[1, 7, 8]

2.1.1 Angles and the formulas used to determine the Sun's position

The angles used to determine the position of the Sun at a certain moment of the day are solar azimuth and elevation angle.[9] The angle used to position the solar panel towards the Sun is the anglebetween the direction of the Sun and the zenith.[10]

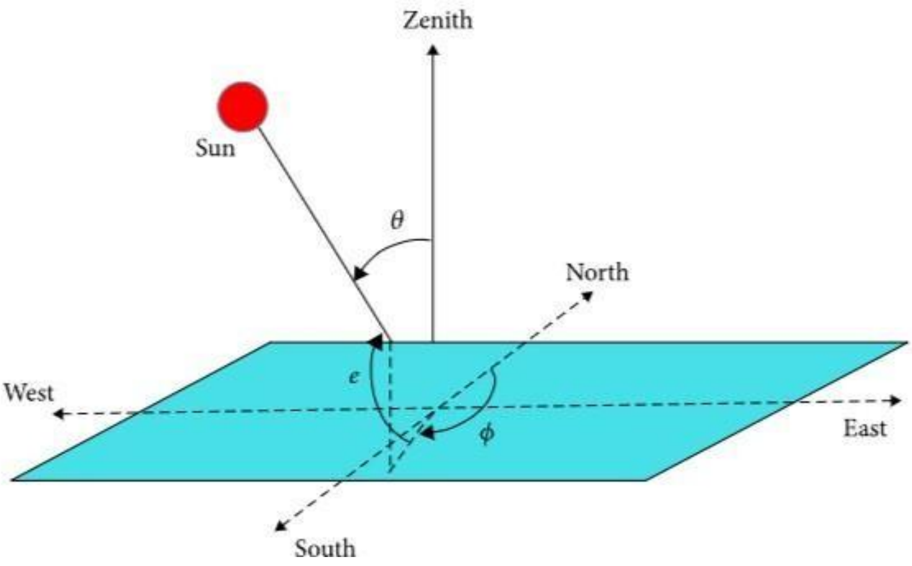

Figure 1 Angles of the Sun's position

Source: https://www.hindawi.com/journals/js/2019/3681031/fig3/

There are two types of solar panels: single-axis and dual-axis. The single-axis solar trackers are moving on the north-south axis, allowing the panel to arc from east to west. With this kind of solar panel, the sunrise and sunset are tracked and it increases the efficiency of the system, without having to install more solar panels. Usually, this type of solar tracker is installed on a flat land an in a warm and dry area.[10, 11, 12]

The dual-axis tracker is moving on two axes, north-south and east-west. The design maximizes the solar energy collected in a year. This type of solar panel is less popular for a solar installation and it can produce up to 45% more energy than the typical static panels.[13] The location of this type of solar panel is a land without tight spaces constrained by a commercial roof space.[10, 12]

For implementing the moving of the solar panel there are two equation of motion, one for the panel and the other one for the motor.

The equation of motion for the panel is:

$$\frac{d^2\theta}{dt^2} = \frac{1}{J}\left(T - K_d \frac{d\theta}{d}\right) \qquad (1)$$

where:
θ - elevation angle
K_d - damping constant
J - inertia
T- torque

The equation of motion for the motor is:

$$\frac{di}{dt} = \frac{1}{L}\left(V - K_g K_f \frac{d\theta}{dt} - Ri\right) \qquad (2)$$

$$T = K_g K_t i$$

where:
K_f - back EMF constant
K_g - gear ratio

L- inductance
R- resistance
K_t- torque constant
i – current intensity

3. Program interface and simulation

The motion of the solar panel and Sun's tracking system is designed in Matlab Simulink version of 2020. The interface from where all parameters are loaded is also designed in Matlab using the Graphical User Interface. For the interface I used static text boxes which labeled the edit text boxes. When the "Simulate" button is pressed, it will create a path between the interface and simulation and all the values of the parameters will be loaded in Simulink.

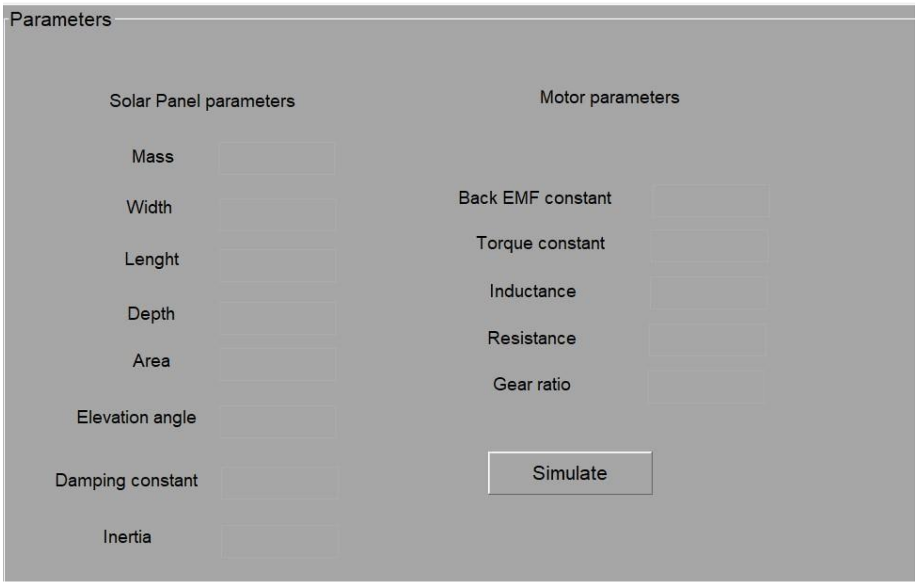

Figure 2 The interface of the parameters

Source: Matlab

3.1 Creating the Simulink model

The steps in creating the simulation of tracking the position of the Sun are modeling the physical system, designing the controller and load the data from the interface in order to create the simulation. In the simulation it was used integrators blocks, gains, constants and the scope for testing the motion. It was also used the PI(s) controller and a step which generates the Sun dates. In the Figure 3 there is a simulation of the panel's motion. In the upper side of the figure there is the basic equation of motion in order to make the panel move.

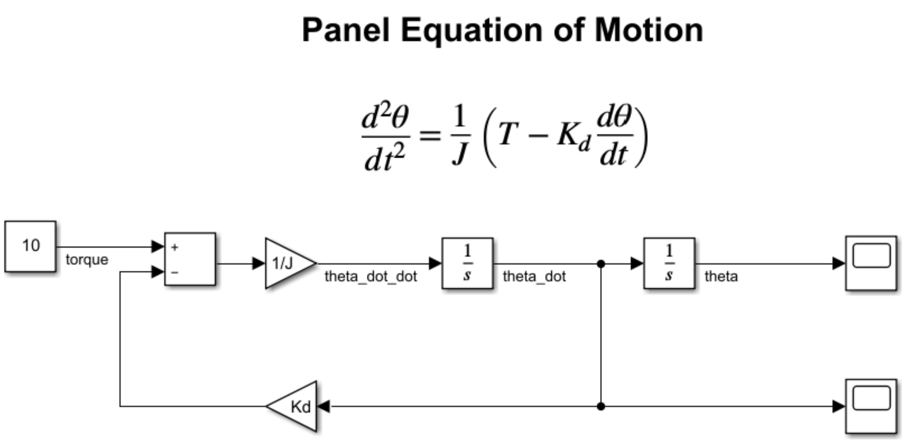

Figure 3 Panel equation of motion

Source: Matlab Simulink

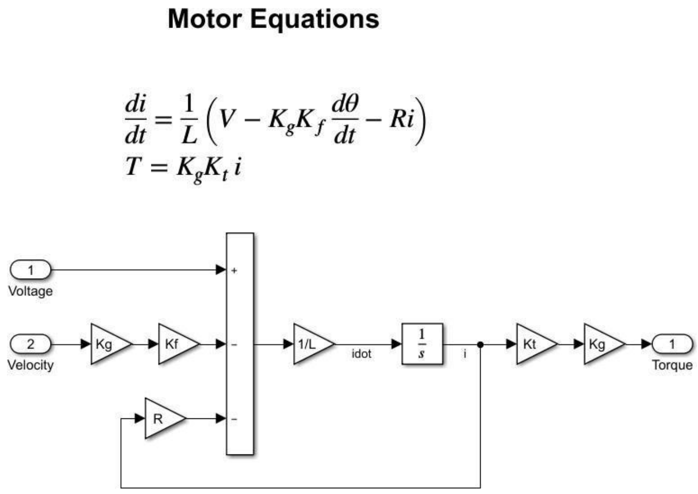

Figure 4 Motor equation

Source: Matlab Simulink

In figure 4 it is reprsented the equation, which is located in the upper part of the figure, that makes the motor functional.

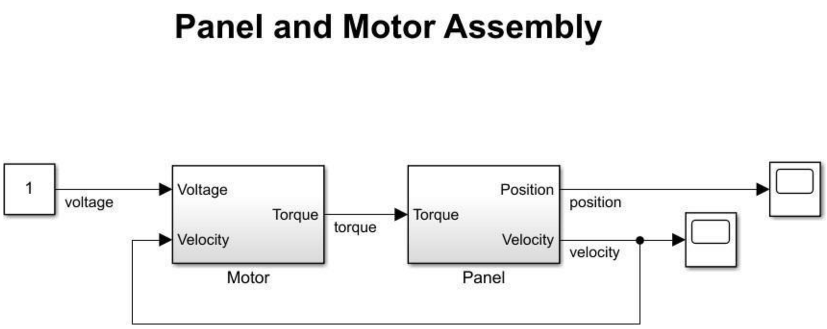

Figure 5 Panel and motor assembly

Source: Matlab Simulink

Figure 5 represents the assembly of the motor and panel, both equation of motion of the two parts of the solar panel are connected. For the Motor, the result of the simulation is the torque of the system and for the Panel, there are the position of th Sun and the velocity of it. The assembly results are shown in the two scopes as graphics.

3.1.1 *Final steps to the result*

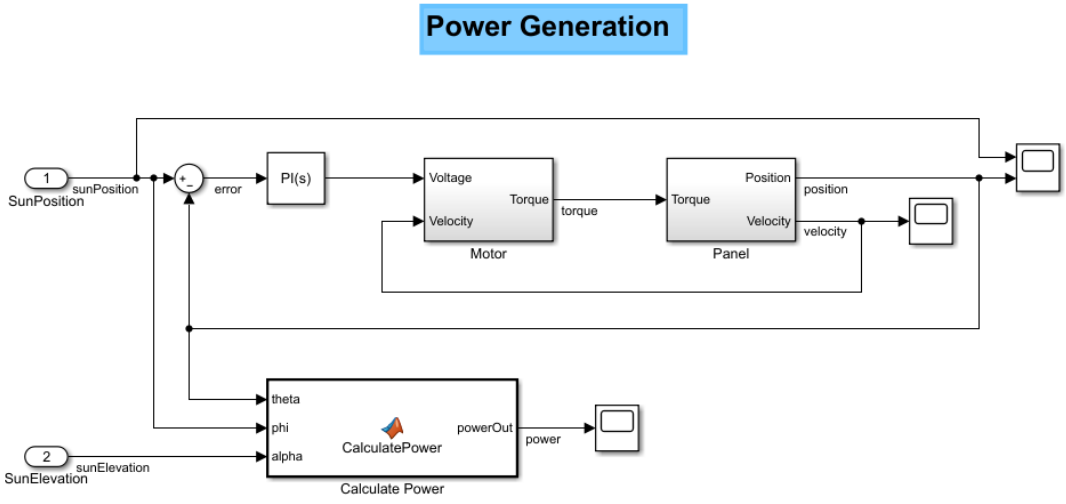

Figure 6 Power generation of the tracking system

Source: Matlab Simulink

In Figure 6 Sun position data is imported into the model and used as reference signal to the controller. The controller outputs voltage to the motor so that the solar panel tracks the sun's position. In this part, the PI controller outputs voltage to the motor in order to rotate the solar panel to a desired position. The reference signal is a unit step. Figure 7 represents the tracking of the Sun position as a result of the simulation.

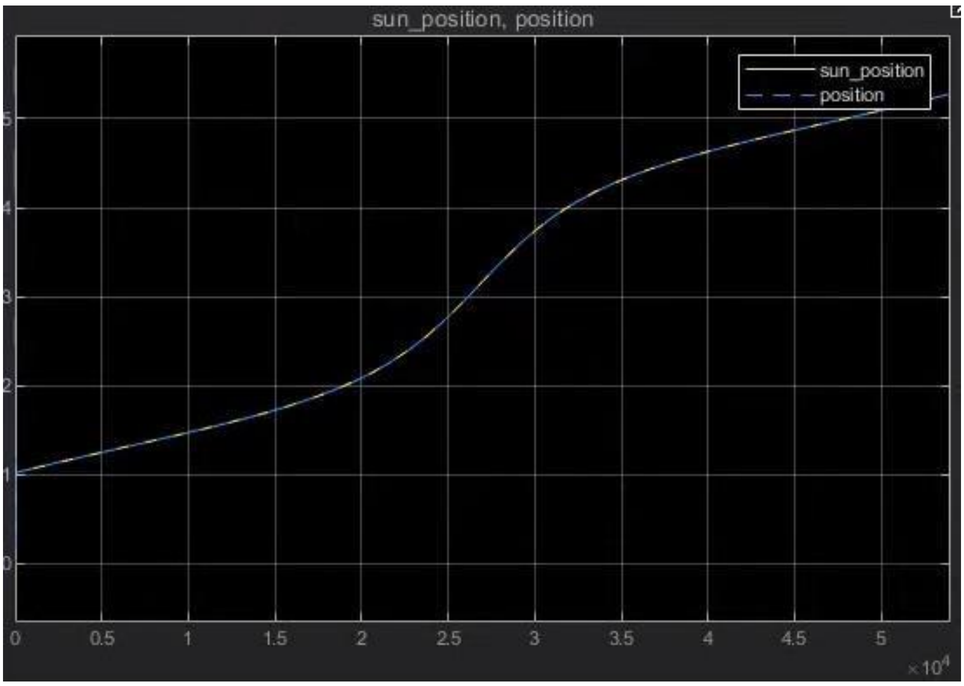

Figure 7 Simulation of the tracking system

Source: Matlab Simulink

4. Conclusion

Compared to the fixed-position panels, solar panels which have a tracker device can follow the trajectory of the Sun all day and collect a far greater amount of energy. As a result it will generate a significantly higher output power. As a novelty, the paper aims to present the motion both of a fixed-position panels and a tracking system of the position of the Sun, using Matlab Simulink. The panel’s movement is directed by the motion of the Sun and it is based on two mathematical equations. For the input data it was used a Graphical User Interface, which allows the user to test the position of the Sun at every moment of the day.

For the future, the dates from a meteorology station can be loaded in the interface in order to eliminate the problems regarding the nebulosity of the sky. Acknowledgement: This paper was supported by grant no. 383/390059/04.10.2021, project cod ID / Cod MySMIS: 120201: Innovative integrated maritime platform for real-time intervention through simulated disaster risk management assistance in coastal and port areas – PLATMARISC.

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