THE EFFECT OF THE ANGLE OF INCIDENCE OF SUNLIGHT ON THE SOLAR PANEL

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Abstract

This paper implements a simple model of solar electricity generation for a solar array in the "Main" building of the Andijan Mechanical Engineering Institute, Andijan, Uzbekistan. This model is compared to recorded data for one specific day near summer solstice, which approximates it well to the maximum possible daily output. In addition, this article calculates the angle of sunlight falling on the solar panel, the movement of the sun during the day, and the parameters of the sun. A solar cadastre is drawn up depending on the geographical location of the place. The influence of the angle of incidence of solar radiation on the efficiency of the solar panel during the summer months is highlighted.

Key words: Solar radiation, local solar time, sunangle, solar array, elevation of the sun

Indroduction

The angle of incidence affects the energy output of a solar cell because it affects how much sunlight the solar cell can absorb.

The angle of incidence is the angle between a light ray and a line perpendicular to the surface of a material. When sunlight shines on a solar panel, it hits the surface at various angles. The solar panel can only absorb light that hits it at certain angles, and so the energy output of the solar panel depends on the angle of incidence [1-2].

The angle of incidence has a major impact on the amount of light that solar cells can absorb. If the rays hit at a larger angle, they will be reflected completely. This means that less sunlight is absorbed by the panel and so it generates less electricity than if the rays had struck more directly [3-4].

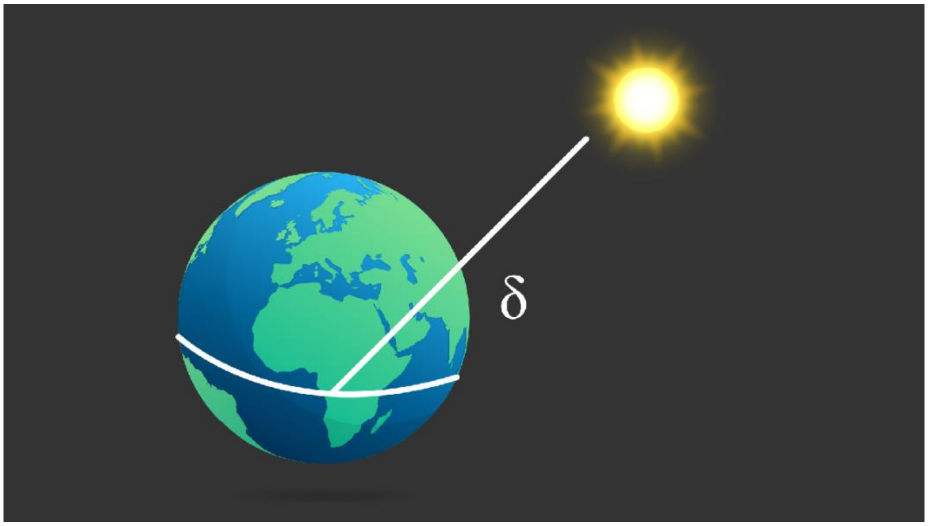
One factor is matching your location's latitude; this minimizes seasonal variations in energy output. Another important consideration is whether you will mount the panels vertically or horizontally. Horizontal arrays capture direct beams from sunrise and sunset better than vertical ones but may lose sunrays between noon and 3 PM depending on where you live. Getting advice from an experienced installer or engineer is usually worth the investment [5-8].

If you are looking to generate energy from the sun, then it is important to consider how much sunlight your solar cells can absorb and what angle they will be in when they do. By understanding these factors and optimizing for them, you can maximize the amount of electricity that your panels generate.

Theoretical power production

Define declination of the sun and latitude of the solar panels.

Declination is the angle of the sun from the equator:



It depends on the time of year.

dec = 23.45 % Summer solstice

lat = 40 + 46/60 % Andijan: 40° 42'

Convert from degrees to radians

dec = deg2rad(dec);

lat = deg2rad(lat);

Make a vector of times from 5:30 to 20 (slightly after sunrise to slightly before sunset). Use 1/4-hour increments (to match measured data).

t = 5.5:0.25:20;

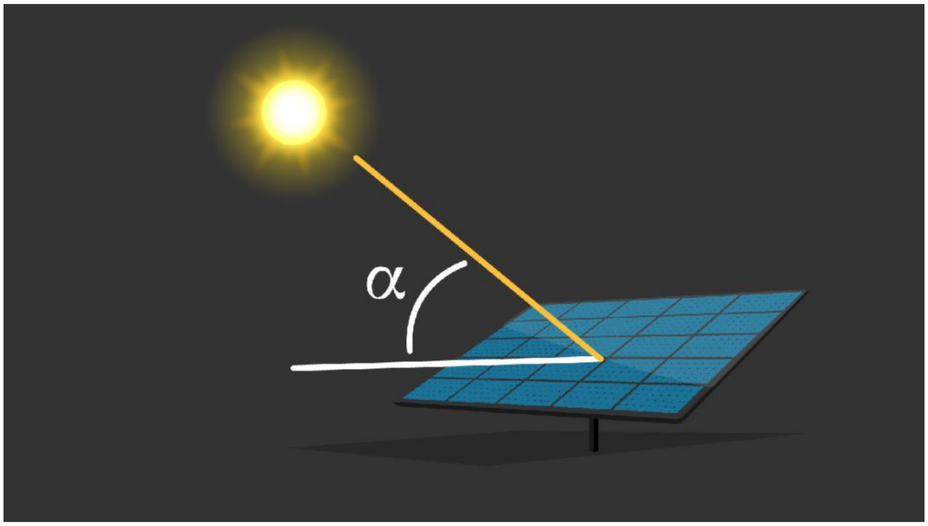
Calculate local solar time. Solar panel longitude is 72° 20' W. EST median longitude is 75°. Time correction is therefore 4*(75-72.33) = 10.68 minutes. Also adjust for daylight savings.

LST = t - 1 + 10.68/60;

Determine the amount of solar irradiance on the solar panels:

$S_{panel} = S_{incident}\sin(\alpha)$, where $S_{incident} = 1.4883 \times 0.7^{\sin(\alpha)^{-0.678}}$ and α is the elevation of the sun, given by

$\sin(\alpha) = \sin(\delta)\sin(\phi) + \cos(\delta)\cos(\phi)\cos(15^{\circ}(LST - 12))$, where δ is the declination of the sun and ϕ is the latitude.

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sunangle = sin(dec)*sin(lat) + cos(dec)*cos(lat)*cosd(15*(LST - 12));
plot(t,sunangle)
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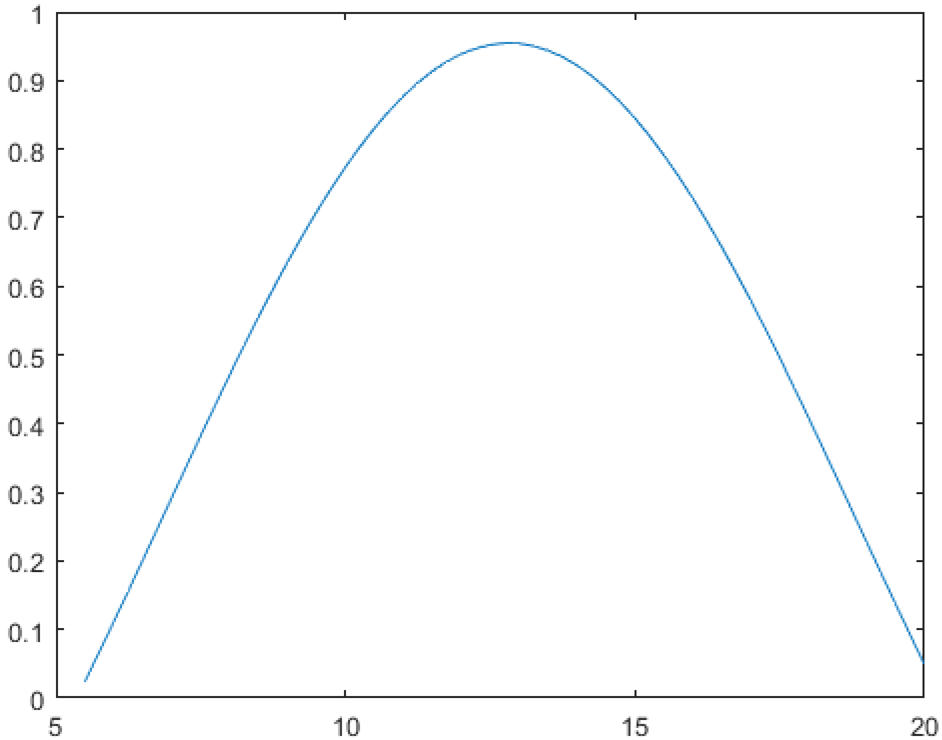
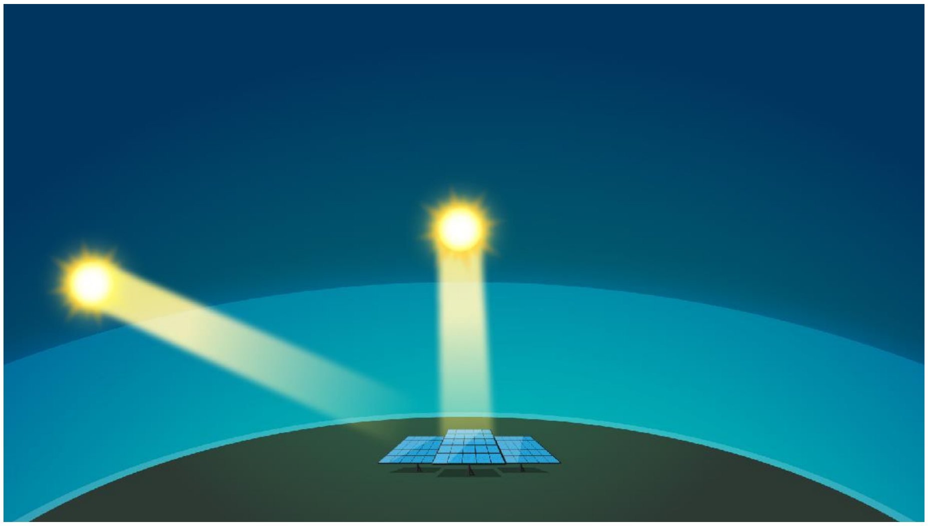


$S_{incident}$ is an empirical formula that models the reduction in incident energy due to the atmosphere - the more air the sunlight has to pass through, the more energy is lost:



S_inc = 1.4883*0.7.^(sunangle.^-0.678);

Calculate the final theoretical production for the whole array of panels, including the inverter limit (210 kW).

production_theory = 250*S_inc.*sunangle;

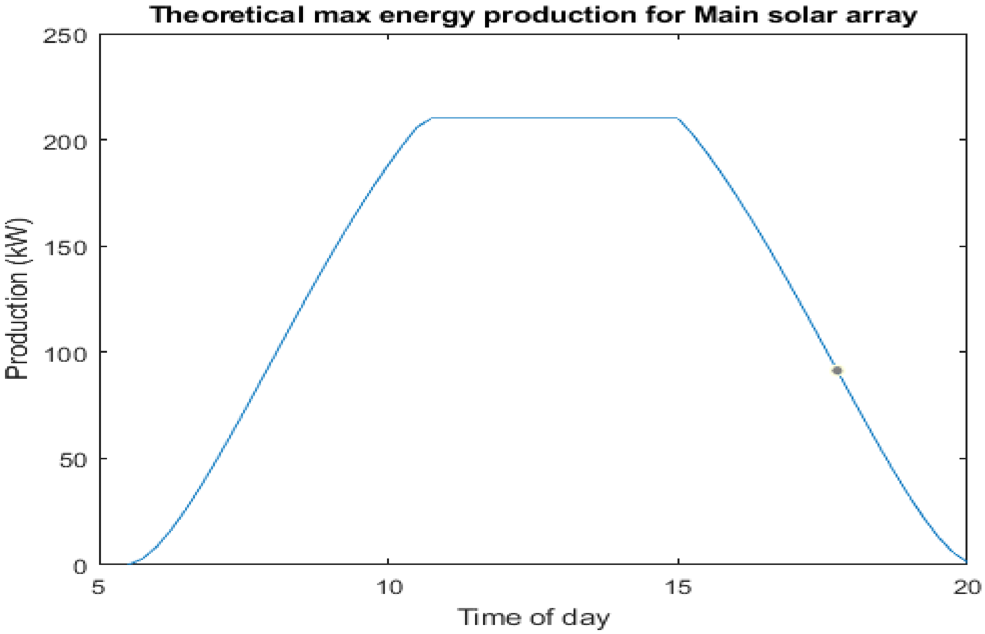
production_theory = min(production_theory,210);

plot(t,production_theory)

xlabel('Time of day')

ylabel('Production (kW)')

title('Theoretical max energy production for Main solar array')



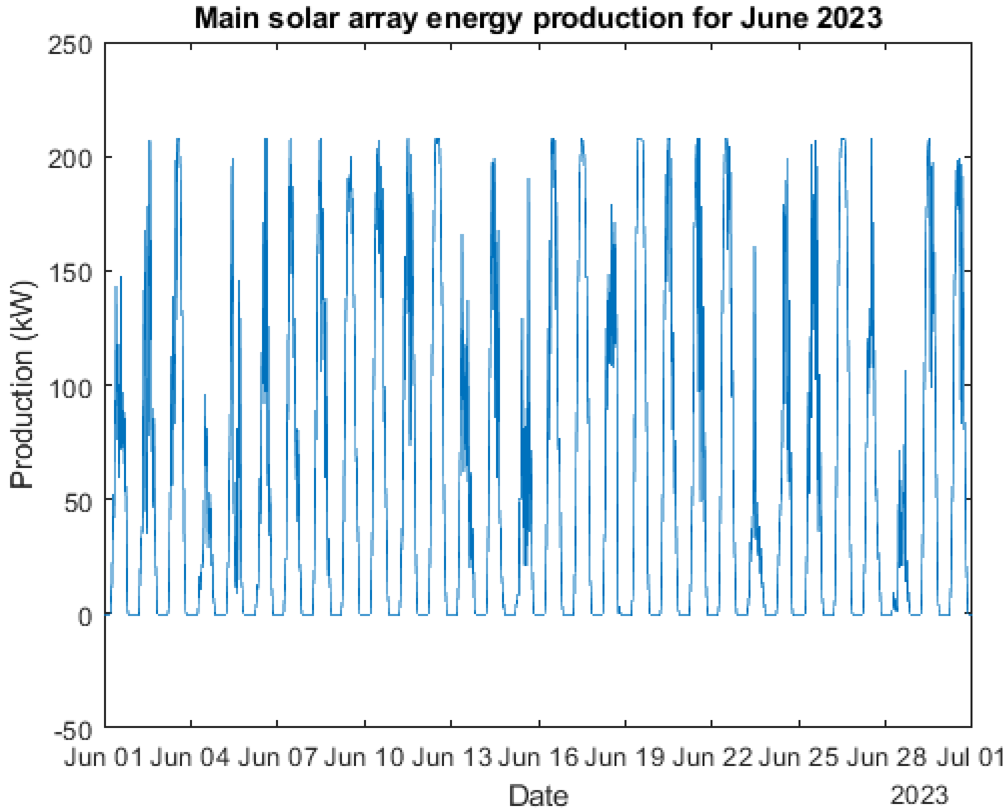
Compare with recorded data

Import data for June 2023 from file.

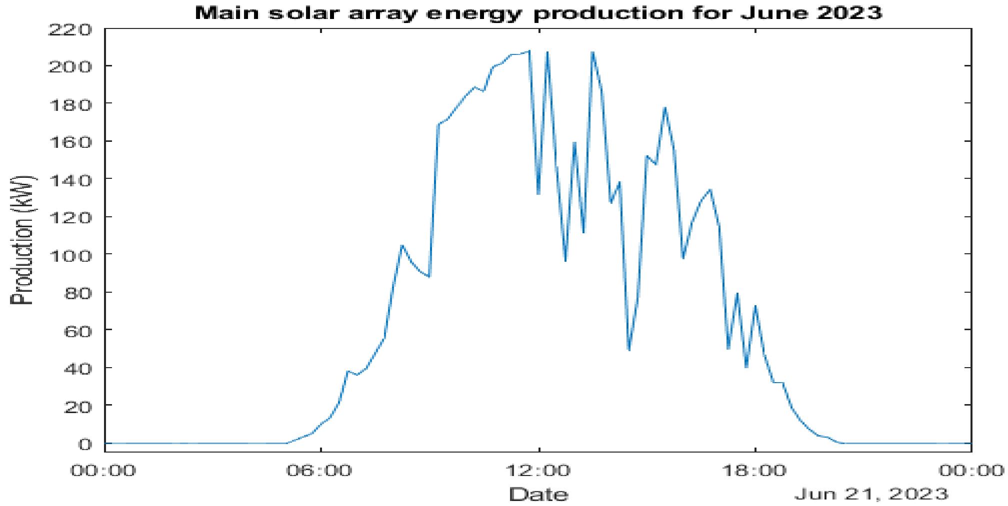
production = readtable("SolarArrayProduction.xlsx"); % equivalent to using the Import Tool

plot(production.Timestamp,production.Main)

xlabel('Date')
ylabel('Production (kW)')
title('Main solar array energy production for June 2023')



Zoom in on June 21 (summer solstice).
xlim(datetime(2023,6,21:22))
ylim([-5 220])



Zoom in on June 26 (completely clear day).
xlim(datetime(2023,6,26:27))
ylim([-5 220])

Reorganize data into a matrix of times by days (4*24 = 96 times, by 30 days).

June2023 = reshape(production.Main,96,30);

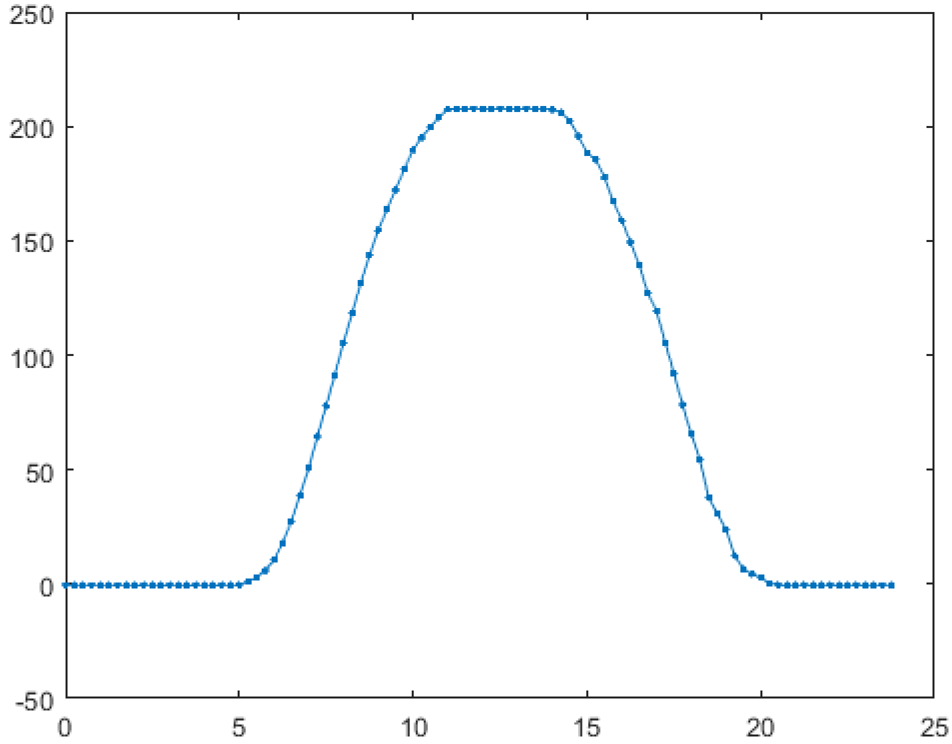
Extract a specific day (June 26 because it is close to the solstice and completely clear).

dayofinterest = June2023(:,26);

Make a vector of times and plot the data for one day.

tfullday = 0:0.25:23.75;

plot(tfullday,dayofinterest,'.-')



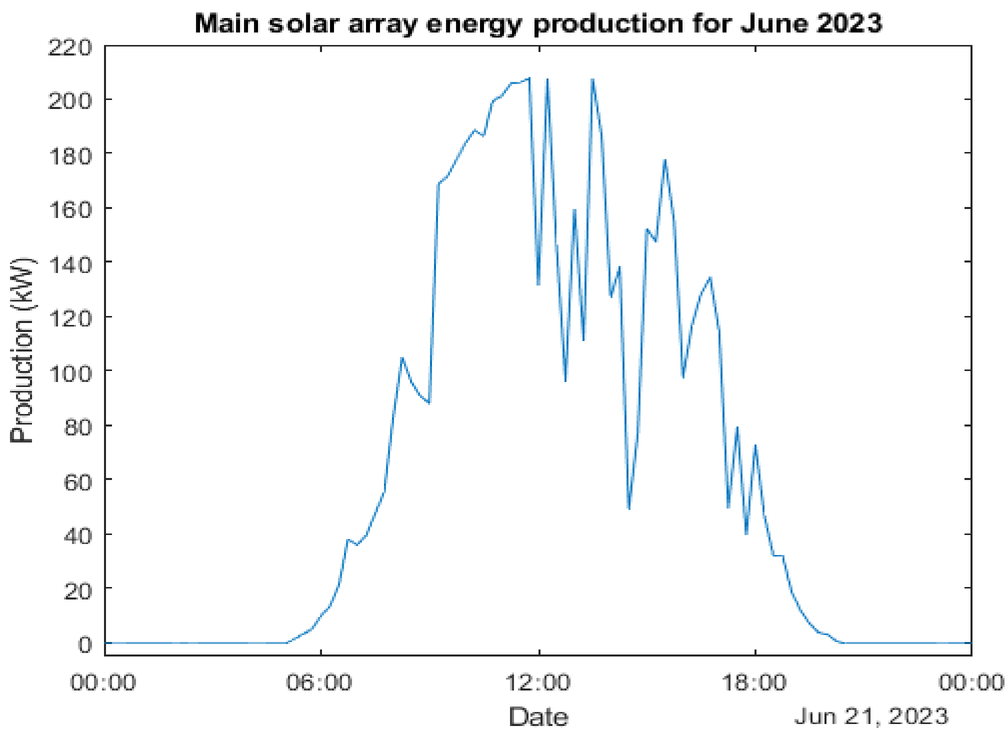
Compare against theory.

plot(tfullday,dayofinterest,'.-',t,production_theory)

xlabel('Time of day')

ylabel('Production (kW)')

legend('Measured data','Theoretical maximum')



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