**Solar Energy Project 2: Modelling Radiation and Electricity Generation**

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**1. Introduction**

In this project, our goal was to model the electricity generated by the solar photovoltaic installation on the rooftop of the Navitas building in Aarhus and compare it with experimentally measured data to assess model accuracy. The project involved modelling hourly global radiation, estimating direct and diffuse radiation, and simulating power generation from the PV modules based on environmental parameters. **Solar Energy Project 2: Modelling Radiation and Electricity Generation**

**Introduction**

This report focuses on modeling the hourly global radiation on a horizontal surface in Aarhus for the year 2018. The assignment involves utilizing solar position equations, weather data from the Navitas weather station, and characteristics of photovoltaic (PV) modules to estimate solar irradiance and electricity generation. Various calculations and models are employed to simulate solar radiation and the power produced by a PV installation, comparing these predictions to historical measurements to assess the accuracy of the model.

**Methods and Theory**

1. Calculating Gt(0) for the first week of February and June 2018

Assuming the formulas below to start :

Eccentricity :.

Declination

Solar Altitude

Solar Azimuth

Equation of Time (ET)

True Solar Time (Omega)

Direct Irradiance on Horizontal Surface (B\_0\_horizontal)

The B\_0\_horizontal formula estimates the direct solar irradiance on a horizontal ground surface. It considers the eccentricity factor, solar altitude angle, and the solar constant (1367 W/m²) to calculate the amount of solar radiation reaching a horizontal surface at a specific day and solar altitude.

Due to Google Earth, we know Navitas Coordinates:

Latitude: 56.15886367°  
Longitude: 10.215740203°

The clearness index () is assumed to be 0.7 for every hour in the timeseries.

To calculate this parameter, we have 3 steps:

1)1. Calculation of B(0)horizontal

The function **calculate\_B\_0\_horizontal()** is utilized to calculate the direct irradiance on the horizontal ground surface (B\_0\_horizontal) for a series of hours throughout the year. It employs solar altitude calculations and solar position equations based on longitude and latitude.

2. Clearness Index

The clearness index () is assumed to be 0.7 for every hour in the timeseries.

3. Estimating Global Radiation (Gt(0))

The global radiation on the horizontal surface (G\_0\_h) is computed by multiplying the clearness index (K\_t) with the calculated direct irradiance on the horizontal surface (B\_0\_h) for each hour.

Solar Position Equations

Equations to determine solar position (azimuth and zenith angles) and global horizontal irradiance (GHI) can be employed. These equations involve calculations related to solar declination, hour angle, and zenith angles based on latitude and day of the year.

Weather Data and Diffuse Fraction

The Navitas weather station data provides cloud cover ratios and temperatures. The diffuse fraction (FD) is estimated as FD = Cloud cover/100, which aids in calculating direct and diffuse radiation on the horizontal surface.

PV Module Irradiance

For PV module irradiance, direct, diffuse, and albedo irradiance calculations are performed. Selection of a diffuse radiation model (isotropic sky or circumsolar diffuse radiation) along with assumptions about reflectivity helps estimate the global radiation on the PV modules.

PV Module Characteristics and Power Production

Using the characteristics of the PV modules (e.g., rated power, tilt angle), the power produced by the installation is estimated hourly, considering irradiance at the module entrance and power reduction due to ambient temperature.

Historical Measured Production

The historical measured production data from the "CTS Data Aflæsning Strom.xls" file is used to compare against the modeled generation. The comparison involves plotting measured production against modeled values for specific weeks in February and June 2018.

**2. Modelling Hourly Global Radiation**

We initiated the project by modelling the hourly global radiation on a horizontal surface (Gt(0)) in Aarhus throughout 2018. Figure 1 illustrates the plotted global radiation for the first weeks of February and June 2018, showcasing seasonal variations.

*[Figure 1: Hourly Global Radiation in Aarhus for February and June 2018]*

**3. Estimating Diffuse Fraction from Cloud Cover**

Using cloud cover ratios obtained from the weather station's data for 2018, we estimated the diffuse fraction (FD) as FD = Cloud cover / 100.

**4. Modelling Direct and Diffuse Radiation**

Utilizing the estimated diffuse fraction, we calculated direct and diffuse radiation on the horizontal surface in Aarhus. Figure 2 depicts the modelled global radiation on the PV module surfaces for the first weeks of February and June 2018, illustrating variations corresponding to seasonal changes.

*[Figure 2: Global Radiation on PV Module Surfaces for February and June 2018]*

**5. Estimation of Power Production from PV Modules**

We estimated the power produced by the installation at every hour, considering the irradiance at the PV module entrance and power reduction due to ambient temperature.

**6. Comparison with Measured Production**

To compare modelled generation with historical data, we plotted the measured production provided by the Facility Management at Navitas. Figure 3 presents the comparison for the first weeks of February and June 2018.

*[Figure 3: Comparison between Measured and Modelled Production for February and June 2018]*

**7. Assessment of Model Accuracy**

We conducted a relative root mean square error (RMSE) analysis between the modelled and historically measured generation on hourly, daily, weekly, and monthly scales. This analysis provided insights into model accuracy and error trends over different time periods.

**8. Conclusion**

This report summarizes our methodologies, findings, and insights gained from modelling solar radiation and electricity generation. The accompanying figures provide a visual representation of the data and comparisons made, supporting our analysis of solar energy potential at the Navitas building in Aar

1. Overview

Our objective in this research was to estimate the electricity produced by the solar photovoltaic installation on the roof of the Navitas building in Aarhus and evaluate the model's correctness by comparing it with empirically observed data. The project comprised simulating power generation from the PV modules depending on environmental conditions, modeling hourly global radiation, and estimating direct and diffuse radiation.

2. Hourly Global Radiation Modeling

In 2018, we started the experiment by simulating the hourly global radiation in Aarhus on a horizontal surface (Gt(0)). Plotted worldwide radiation for the first weeks of February and June 2018, including seasonal changes, is shown in Figure 1.

[Figure1: Aarhus, Denmark, Hourly Global Radiation for February and June 2018]

3. Utilizing Cloud Cover to Estimate Diffuse Fraction

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We calculated the diffuse fraction (FD) using cloud cover ratios from the weather station's 2018 data, which is equal to FD = Cloud cover / 100.

4. Direct and Diffuse Radiation Modeling

We computed direct and diffuse radiation on the horizontal surface in Aarhus using the expected diffuse fraction. Figure 2 shows variations in global radiation that correlate to seasonal changes on the PV module surfaces between the first weeks of February and June 2018.

[Figure 2: February and June 2018 Global Radiation on PV Module Surfaces]

5. Calculating PV Module Power Production

Taking into account the irradiance at the PV module entrance and power loss because of, we calculated the power generated by the system at each hour.

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Taking into account the irradiance at the PV module entrance and power loss from ambient temperature, we calculated the power generated by the installation at each hour.

6. Evaluation in Light of Measured Production

We showed the measured production provided by Navitas Facility Management to compare the modeled generation with historical data. The comparison for the first weeks of February and June 2018 is shown in Figure 3.

[Figure 3: February and June 2018 Measured and Modeled Production Comparison]

7. Evaluation of Model Precision

On hourly, daily, weekly, and monthly timescales, we performed a relative root mean square error (RMSE) comparison between the historically measured generation and the simulated generation. This investigation revealed patterns in model accuracy and error across